National Park Service
U.S. Department of the Interior

Water Resources Division
Natural Resource Program Center

Technical Report NPS/NRWRD/NRTR-2006/347

ASSESSMENT OF COASTAL WATER RESOURCES AND WATERSHED CONDITIONS AT SITKA NATIONAL HISTORICAL PARK, ALASKA

Ginny Eckert, Eran Hood, Carrie Talus, and Sonia Nagorski

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Assessment of Coastal Water Resources and Watershed Conditions at Sitka National Historical Park, Alaska

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Technical Report NPS/NRWRD/NRTR- 2006/347

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January 2006

This report was prepared under Task Order J9W88 04 0016
of the Pacific Northwest Cooperative Ecosystem Studies Unit (agreement CA90880008)

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

Acknowledgments

We would like to thank numerous people for their help in the preparation of this report. Geoffrey Smith, Biologist, Gene Griffin, Chief of Resource Management, and Greg Dudgeon, Superintendent, were very helpful and provided information about the park. Scott Gende, Mark Flora, Jim Tilmant, Kristen Keteles, Bill Hansen and Park Biologist, Geoffrey Smith, provided extensive comments on the draft report, which improved the final product. Edwin Knuth at UAS created original maps for the report.

Commonly used abbreviations

ADEC – Alaska Department of Environmental Conservation
ADFG – Alaska Department of Fish and Game
ADNR – Alaska Department of Natural Resources
CBS - City and Borough of Sitka
EMAP – Environmental Monitoring and Assessment Program (of the EPA)
EPA – US Environmental Protection Agency
HAB – Harmful Algal Bloom
NADP - National Atmospheric Deposition Program
NOAA – National Oceanic and Atmospheric Administration (in the US Department of Commerce)
NPDES – National Pollutant Discharge Elimination System (of the EPA)
NPS – National Park Service (in the US Department of the Interior)
POPs – Persistent Organic Pollutants
SITK– Sitka National Historical Park (National Park Service designation)
SJC - Sheldon Jackson College
UAS – University of Alaska Southeast
USDA – US Department of Agriculture
USFWS - US Fish and Wildlife Service (US Department of Interior)
USGS – US Geological Survey (in the US Department of the Interior)

Executive Summary

Sitka National Historical Park (SITK) is located in Southeast Alaska on the west side of Baranof Island. The 45.2 ha (113 acre) park lies within Sitka Sound between Crescent Bay and Jamestown Bay and comprises the riparian zone adjacent to the Indian River, an estuary delta, floodplain and coastal intertidal area. SITK was established as a national monument in 1910 to commemorate the 1804 Battle of Sitka and to preserve cultural and historical sites and artifacts related to this battle. It is Alaska's oldest federally designated park. Today the main activities in SITK are tourism and recreation.

The focus of this report is the coastal water resources within and around SITK, which consist of both freshwater and marine ecosystems. The Indian River and Indian River watershed extend well outside of SITK boundaries, and therefore, most of the current issues with this watershed lie outside the park. SITK leases 6,295 sq. m (69,943 sq. ft) of tidelands from the City and Borough of Sitka (CBS) and 19.2 ha (47.915 acres) of tidelands from the State of Alaska. These long term tidelands leases provide protection for salmon spawning habitat and preserve the natural and cultural resources of the Park within the intertidal zone.

The purpose of this report is to provide a comprehensive inventory and assessment of the current condition and possible impairments, both natural and anthropogenic, of water resources in the coastal region of SITK, based on currently available data and information. In addition, the report identifies gaps in data and information that hinder the assessment of water resources and provides recommendations for future monitoring and mapping of coastal water resources. The diversity and quality of freshwater and marine habitats affects plants and animals within the park and provides aesthetic and recreational opportunities for park users.

The climate in southeast Alaska is dominated by a persistently-located area of low pressure known as the Aleutian Low. This area of low pressure generates powerful winter storms, which routinely produce >15 m waves and gale strength winds; however SITK, located within Sitka Sound, is buffered from the open ocean by several offshore islands. The Aleutian Low oscillates in strength and location throughout the year, but maintains its influence on the regional climate of SITK, which is characterized by heavy precipitation (annual average precipitation at SITK is 245.4 cm (96 in)) and moderate temperatures with average daily temperatures ranging from -0.5 to 13 ºC (33 to 55 ºF). Streamflow variations in the Indian River closely track precipitation events, which peak during September through November.

SITK's biological resources are diverse, given the wide range of ecological units within a small area. The intertidal area consists primarily of boulder and cobble substrate, which provide habitat for a diverse group of marine biota. Marine mammals do not reside within the small area encompassed by SITK, however many species are observed nearby. Vegetation in the upland region of SITK is dominated by coastal temperate rainforest typical of Southeast Alaska, consisting of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*), with alder (*Alnus rubra*) growing near the Indian River. Old-growth forest characteristics are found in the northeast corner of SITK such as multiple canopy layers, trees of varying diameters, snags, and woody debris; and Sitka spruce in the area are up to 500 years old. Upland fauna in SITK include many species of birds and mammals, both resident and transient. The Indian River is important habitat for macroinvertebrates, benthic algae, and many anadromous fish species, including four species of salmon.

Biotic, physical, and chemical parameters, such as specific conductance, pH, water temperature, dissolved oxygen, major ions, nutrients, organic carbon, and suspended sediment, indicate that the water quality of the Indian River is good to excellent. Concentrations of arsenic, chromium, copper, nickel, and zinc may be naturally high. The Alaska Department of Environmental Conservation does not list the Indian River or any area nearby that could affect the Indian River as a contaminated site. This watershed is considered to be healthy and is relatively pristine, and does not violate any of the criteria for Alaska's water quality standards.

Water quality in Sitka Sound appears to be high, however little monitoring has been conducted. The CBS has monitored water quality in receiving waters of the wastewater facility in accordance with their NPDES permit since the 1980s. Our review of monitoring summary reports from 1997, 1999, and 2002-2005 revealed that the wastewater facility does not exceed state water quality standards or permit limitations, and water quality in Sitka Sound, even within close proximity to wastewater discharge, is good. Water quality in marine waters was recently surveyed by the Environmental Monitoring and Assessment Program (EMAP), which sampled throughout Southeast Alaska in 2004; however results were not available at the time of report writing. The effects of cruise ships on Sitka Sound water quality are largely unknown.

Only minor water quality impairments or possible problems exist in SITK. Historically, a 0.3 ha (0.75 acre) site contained an asphalt plant from 1957-1961 on the northeast bank of the Indian River near the mouth. NPS monitoring of water quality, soil contamination, and bank erosion in the last four years (2002-2005) has not found contamination or impairment at the site. Drainage ditches from the Sheldon Jackson College (SJC) property run into the Indian River within SITK. Water quality monitoring by SITK park personnel once found one instance of fecal coliform levels over the state limit in the drainage, which originally reached the Indian River via a ditch, but SITK has since put in a culvert and filled in the ditch. SITK continues to monitor water quality of this drainage and the SJC tributary periodically. Petroleum spills may cause water quality impairment in Sitka Sound, however but we estimate that vessel traffic is quite low compared to other regions of the US. The mouth of the Indian River has a Geographic Response Strategy (GRS), created through DEC and other agencies, which is intended to protect a specific sensitive area from oil impacts following a marine vessel spill.

Urbanization and ongoing development pose a threat to water quality and habitat in the Indian River within and above SITK; however past studies of water quality and sediment transport in the Indian River suggest that urban runoff is not detectably affecting water quality. To date, development near the Indian River has occurred only in the lower areas of the watershed. The upper watershed is completely surrounded by National Forest Service land that has not been harvested for timber. The CBS owns land next to the Indian River that is zoned as residential and where housing units have been and continue to be developed. Other development projects that are in the process of being planned include a landfill, a public safety academy driver training course, Sitka Counseling and Prevention Services (SCPS) housing and parking improvements, Sitka and Indian River trail improvements, and a CBS Electrical Department extension. Each of these development plans has the potential to adversely impact water quality in the Indian River watershed.

A major area of concern with the Indian River is the maintenance of adequate instream flow and associated changes in sediment dynamics as a result of diversions from CBS and SJC. CBS maintains a diversion facility 2.25 km (1.4 mi) from the mouth of the river. SJC maintains a diversion flume at 1.3 km (0.8 mi) upstream from the mouth of the river. Natural low flow events occur in the winter, when much water is held as snow and ice, and during sustained high-pressure weather systems that produce relatively dry climatic conditions in the region. Dams trap a large amount of coarse sediment that would otherwise be carried downstream. By starving the downstream channel of sediment, a dam promotes the scour and erosion of riverbanks downstream. Diminished streamflow and changes in sediment dynamics in the lower channel may have deleterious effects on macroinvertebrate habitat and fish spawning sites.

SITK, like many pristine high-latitude areas, is currently at risk from atmospherically derived contaminants. Mercury and a group of chemicals known as Persistent Organic Pollutants (POPs) are the two primary contaminants of concern for Alaska. Levels of these pollutants have not been monitored in SITK; however sediment cores collected in nearby Glacier Bay National Park indicate that rates of mercury deposition in the area have been rising consistently since the Industrial Revolution. In addition, a study of sea bird eggs in the Gulf of Alaska found elevated levels of POPS.

Non-indigenous invasive species that have been introduced or are moving into Alaskan waters include multiple species of fish, plants, and invertebrates. Pathways of introduction in aquatic and marine systems include fish farms, aquaculture, transport in ballast water from ships, live seafood trade, and sport fishing gear. There has not been a comprehensive survey of aquatic and marine invasive species in SITK. Atlantic salmon could become a nuisance species if they were to establish in the river, however they have not been observed to date. Surveys of exotic plants found at least six species of exotic plants within park boundaries. The NPS is taking steps to eradicate Japanese knotweed and creeping buttercup because of their abilities to spread and negatively impact native species.

Very little is known about harmful algal blooms, which are caused by a few dozen marine phytoplankton that produce toxins. Harmful algal blooms have been documented for centuries in Southeast Alaska. The earliest recorded event in Alaska was in 1799 when a party of Aleut hunters under the command of a Russian fur trading company ingested mussels. Within minutes, half the party experienced nausea and dry mouth, and two hours later, 100 hunters had died. Alaska has figured prominently in the discovery of HABs and associated toxins, as the family of toxins responsible for PSP were named saxitoxins because they were extracted from the butter clam *Saxidomus giganteus* from Peril Strait, just northeast of Sitka. NPS should advise against non-commercial harvests of shellfish because of the risks associated with PSP.

Climate change is an important natural resource issue for national parks in Alaska, and recent research suggests that changes in climate may dramatically impact water resources in Alaskan parks. The most obvious effects of climate change on hydrologic resources in Alaska are changes in the extent of permafrost, snow cover, glaciers, and sea and lake ice cover. Currently, glaciers in Southeast Alaska are thinning at rates as high as 4 meters per year. The most likely impact of climate change on hydrology of the Indian River watershed would be an increase in winter streamflow levels, as more precipitation falls as rain rather than snow.

Our evaluation of the status of resources and a list of recommendations are included below.

Indicator	Freshwater / Indian River	Estuary	Marine/ Intertidal
Water Quality			
Eutrophication	OK	OK	OK
Contaminants	PP	PP	PP
Hypoxia	OK	OK	OK
Turbidity	OK	OK	OK
Pathogens	OK	OK	OK
Habitat Disruption			
Physical benthic impacts	OK	OK	OK
Coastal development	PP	PP	PP
Altered flow	EP	OK	OK
Erosion/Sedimentation	EP	EP	OK
Altered salinity	NA	OK	OK
Other Indicators			
Harmful algal blooms	NA	PP	PP
Aquatic invasive species	PP	PP	PP
Impacts from fish/shellfish harvesting	PP	OK	OK
Climate change	PP	PP	PP

Definitions: EP= existing problem, PP = potential problem, OK= no detectable problem, shaded =limited data, NA= not applicable.

List of recommendations
Data access/management
1. Online archives of NPS publications and reports
2. Integration of information into centralized and web-accessible GIS

Water quality
1. Monitoring of water quality in the Indian River
2. Targeted monitoring of effects of nearby development

Biological resources and habitats
1. Intertidal monitoring program
2. Identification of sentinel species
3. Vessel survey

Hydrology/Oceanography

1. Identification of generalized circulation in Sitka Sound
2. Monitor streamflow, sedimentation, and erosion in the Indian River and estuary
3. Monitor physical parameters to detect how changes in climate may be affecting hydrologic resources

A. Park Description

A1. Background

A1a. Setting

Sitka National Historical Park (SITK), a small parcel of approximately 45.2 ha (113 acres), is located in Sitka on the west side of Baranof Island in Alaska's panhandle (Figure 1). The park lies within Sitka Sound between Crescent Bay and Jamestown Bay and comprises the riparian zone adjacent to the Indian River, an estuary delta, and a floodplain (Figure 2). The northeast park boundary runs along Sawmill Creek Road, the west side of the park borders Sheldon Jackson College property, and the southern park boundary, comprising almost 2 km (1.24 mi), is coastline and river delta (Figure 1). In Alaska the National Park Service (NPS) generally has jurisdiction only over portions of coast above the mean tide line; however, SITK leases 6,295 sq. m (69,943 sq. ft) of tidelands from the City and Borough of Sitka (CBS) and 19.2 ha (47.915 acres) of tidelands from the State of Alaska (CBS 1972). The lease from CBS was issued in March of 1972, and expires 55 years later in March 2027. The lease from the state was issued in March 1973 and expires 55 years later in March 2028. These long term tidelands leases protect salmon spawning habitat and preserve the natural and cultural resources of the Park within the intertidal zone (Geoffrey Smith, NPS- SITK, personal communication 2005).

The boundaries of SITK encompass the lower reach of the Indian River and the majority of the Indian River Delta (Figure 3), and as a result, this watershed is an important natural resource of SITK. The Indian River flows through a U-shaped, large, post-glacial valley that includes Mt. Verstovia, Arrowhead Peak, the Sisters, and Gavan Hill (Figure 4). This watershed ranges in elevation from 0 to 1158 m (3800 ft), encompasses a drainage basin of approximately 19.8 km (12.3 mi), and has annual average precipitation of about 254 cm (100 in). Muskeg wetlands within the watershed are an important resource for holding and releasing water and for sedimentation and filtration of storm water runoff. The section of the Indian River within SITK is 1 km (0.64 mi) long and includes the entire mouth of the river. The river is widest at its mouth during high tide with a width of approximately 1 km (0.64 mi). The Indian River has shallow, well-drained soils, high drainage density, and steep topography (Brewer 2001), and the section of the Indian River that flows through SITK can be characterized as a low gradient, gravel-cobble bed, alluvial channel.

The vegetation within SITK is coastal temperate rainforest, which is typical in Southeast Alaska and is dominated by western hemlock and Sitka spruce. Most of the SITK landforms originated from late Wisconsin glacial deposits and have been shaped by isostatic rebound, plate tectonics, human use, ocean tides, and the Indian River. Active tectonics in the region and the increased thinning of glaciers are both contributing to the high rates of uplift in Southeast Alaska. During the last 9,000 years, SITK lands have experienced regional uplift of approximately 12.2 m (40 ft) to 19.8 m (65 ft) (Yehle 1974). This uplift, coupled with ocean and river processes, has created multi-aged river terraces, floodplains, beach ridges, and tidal meadows that currently make up the landforms of the Park.

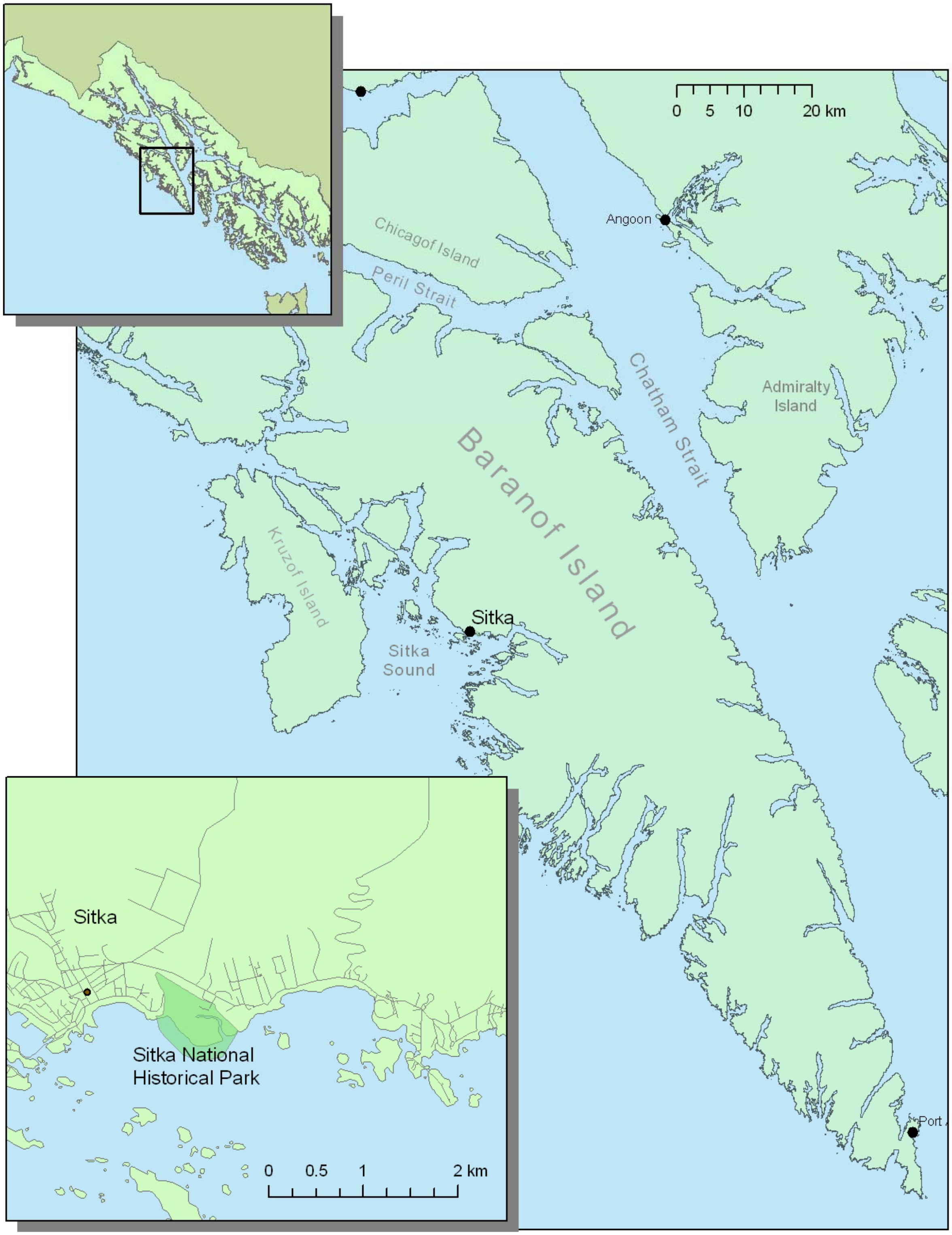

Figure 1. Location of Sitka National Historical Park within Southeast Alaska

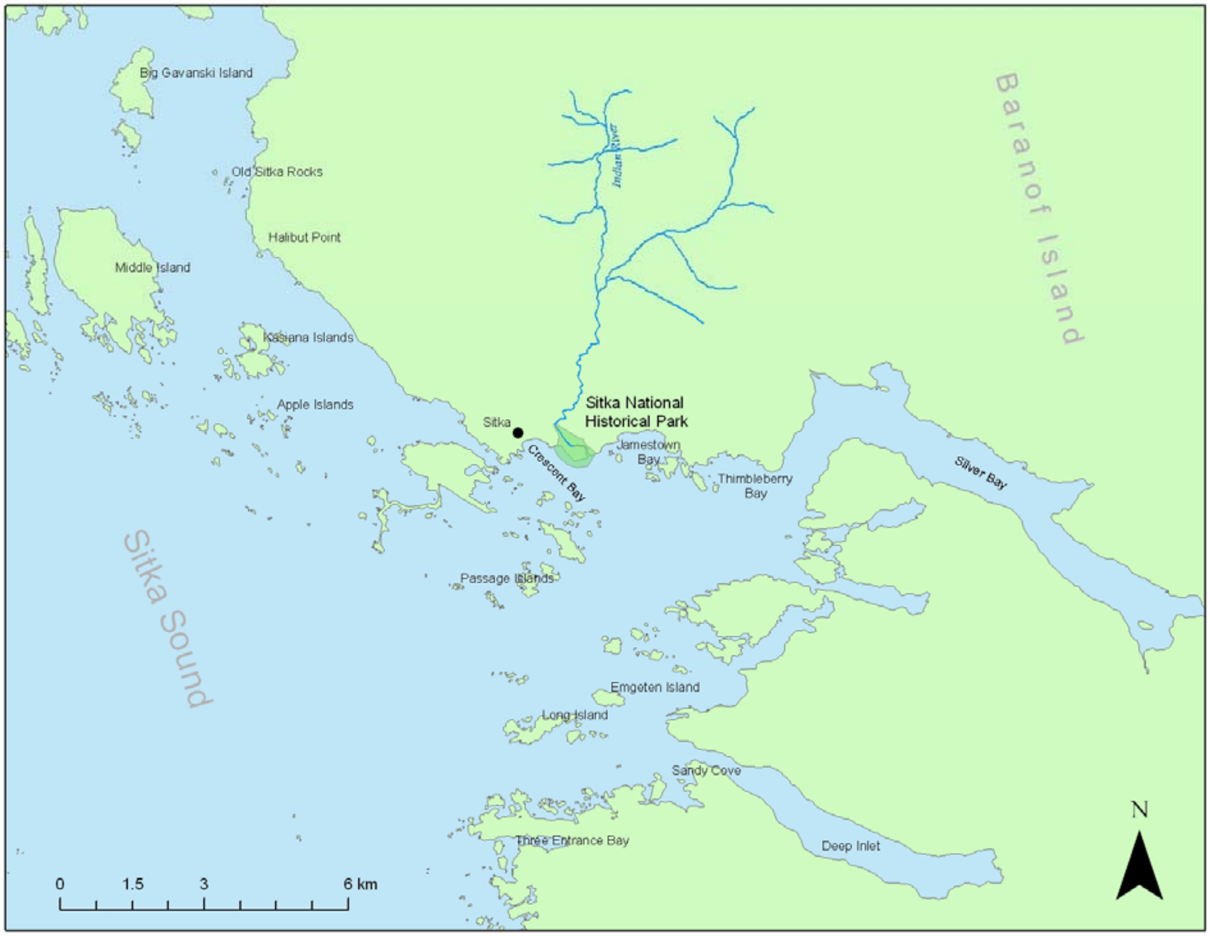

Figure 2. Sitka National Historical Park and its relationship to the Indian River and Sitka Sound

Figure 3. Aerial image and boundary for Sitka National Historical Park.

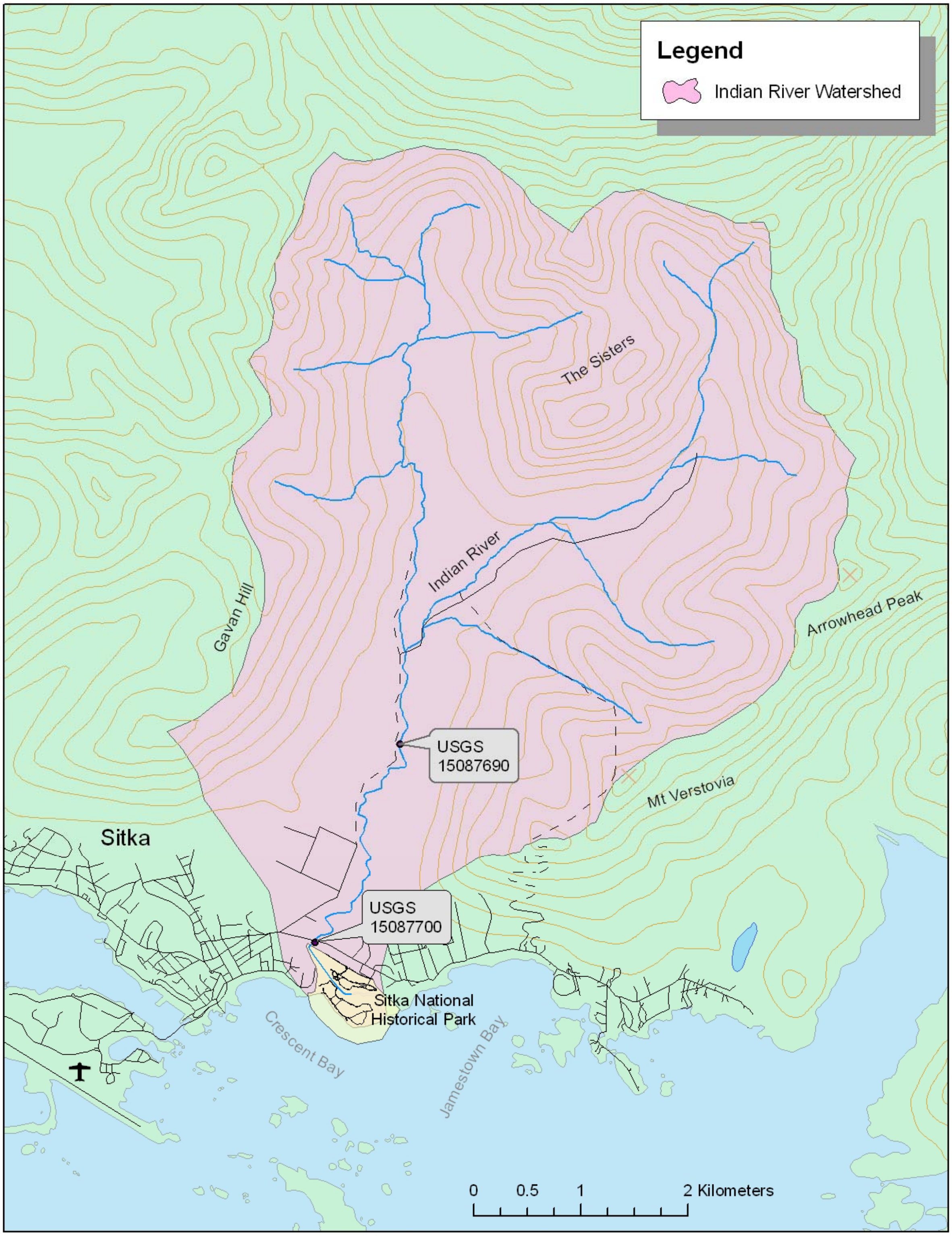

Figure 4. Indian River watershed.
USGS gages are located outside the Park at the locations indicated.

A1b. Human Utilization

Human disturbance has greatly influenced the lower Indian River flood plain and estuary throughout recorded history. The first known peoples of the area are the native Alaskan Tlingit tribe, who has occupied Southeast Alaska for possibly the last 10,000 years (Antonson and Hanable 1987). It is not known when the Tlingit first occupied Sitka Sound, but there is evidence of settlement for the last 600-800 years (Erlandson 1990). The oral history of the Kiksadi Tlingits indicates that a permanent village was established there for many years before European contact (Antonson and Hanable 1987). The first known contact of Sitka Tlingits with Europeans was in the mid 1700s, and records show that the Tlingits were extremely wary and threatening to early European explorers and fur traders. These peoples survived by relying on the ocean for most of their food, supplementing their diet with berries and game. The SITK area may have been used for berry gathering, hunting, drying fish, collecting seaweeds and other food in the intertidal and fishing in the Indian River.

The first European landing in the Sitka area was led by Alexei Chirikov, the commander of the St. Paul, of one of the ships in the second Russian Bering expedition (Antonson and Hanable 1987) in 1741. In 1778, the British explorer Captain James Cook came to the area and advertised the quality of local sea otter pelts to the world (Antonson and Hanable 1987). Not long after, Russians, British, Americans, and others were hunting and trading in the area, and eventually the Russians gained control over trading operations through negotiations with the Tlingits. In 1799 Alexander Baranov arrived in Sitka Sound to control the lucrative fur trade and to establish a trading post and Russian settlement. Relations between Russians and Tlingits worsened over time, and in June 1802, the Tlingits attacked and destroyed the Russian settlement (Dauenhauer 1990).

In 1804, Baranov and other Russians avenged the 1802 attack by raiding the Tlingit fort located near the current site of SITK, resulting in a 6 day battle after which the Russians took over the Tlingit's abandoned fort and proceeded to build a new settlement, called Novo Archangelsk or New Archangel (Antonson and Hanable 1987). In August 1808, New Archangel, now known as Sitka, became the capital city of Russian America and the center for Russian fur trading (Antonson and Hanable 1987). During this time, the Russians claimed land in North America that stretched along the coast from Norton Sound to California, and Sitka was the cultural and commercial center for these Russians in North America (Antonson and Hanable 1987).

During the 19th century many changes occurred in the Sitka region, while the remaining Tlingits attempted to maintain their traditional lifestyles. In the 1820s, the Tlingits continued to use the Indian River for fishing activities (Dean 1993). In the 1830s, 1840s, and 1850s, Russians established gardens along the Indian River and built various housing and commercial buildings (Longenbaugh 1968, Fedorova 1973). By the 1840s sea otters became extinct in Alaskan waters, impacting the fur trade. Alaska was transferred to United States ownership in 1867. Afterward many who came to Sitka were gold prospectors, and in 1870 gold was found nearby in Silver Bay (Antonson and Hanable 1987). To reach the mining sites, a bridge was built over the lower portion of the Indian River in 1888. By 1870, Sitka residents were increasingly using the Indian River trail for recreation walks (Cracroft 1981), and Tlingits were continuing to use the mouth of the river for seasonal fishing activities as well as collecting wild celery and salmonberry sprouts in the region, and seaweeds and other leafy green plants near the beach line (Hope 1992).

SITK was established as a federal park in 1890 and became a national monument in 1910 to commemorate the Battle of Sitka and to preserve cultural and historical sites and artifacts related to this battle. It is Alaska's oldest federally designated park. After becoming a national monument, government and public activity along the mouth of the Indian River increased. From the end of the 1800s to about 1940, development occurred in SITK that included road construction along the north bank of the Indian River, new footpaths, improvement of existing footpaths, and improvements to bulkheads along the riverbank to stave off erosion (Antonson and Hanable 1987). In 1940, two pit toilets were constructed and a building was purchased at the entrance to the monument. The existing visitor center was completed at the entrance to SITK in 1965 (Antonson and Hanable 1987) and was remodeled in 2002 (Geoffrey Smith, NPS-SITK, personal communication 2005).

During World War II, the US military was prepared for a Japanese attack on Sitka and set up observation posts, machine gun pits, and a water pipeline along the Indian River including areas within SITK (Antonson and Hanable 1987). From 1939 to 1979, gravel dredging operations by the military took place at the mouth of the Indian River and in the Park's intertidal zone. This caused serious bank erosion problems along the river and left large, deep holes in the intertidal zone that remain today (Antonson and Hanable 1987). At the conclusion of operations, both the Army and the Navy restored areas along the Indian River, including removal of buildings, equipment, and the installation of log cribbing to protect the bank of the Indian River (Shannon & Wilson 1995). In 1957, an asphalt batch plant was set up on the northeast bank of the Indian River (outside SITK) to pave Halibut Point Road (Shannon & Wilson 1995). This asphalt plant stopped operations sometime between 1959 and 1961 and was barged off site, while debris such as cable, machinery and metal was buried at the site (see *B3a Point Sources of Pollutants* for pollution concerns) (Shannon & Wilson 1995). The northeast bank near the mouth of the Indian River was filled to create a place for asphalt plant operations. Additional fill was added to the river to extend the existing trailer park that is located outside SITK. These alterations to the river's flow regime have created concern over changes in shoreline erosion (see *C6a. Erosion*).

Today the main activities in SITK are tourism and recreation. In 2003, 251,648 visitors came to SITK, and 298,319 came in 2004 (NPS 2005), and the vast majority of these visitors came in the summer. Visitors come to Sitka primarily by jet airliner or by cruise ship. A few arrive via the Alaska state ferry system. The Alaska Department of Fish and Game (ADF&G) has closed the Indian River to salmon fishing which includes the river within SITK, however, some fishing occurs in the estuary near the mouth (outside markers posted by ADF&G). The historical subsistence fishery that occurred in this portion of the Indian River no longer exists; however a new development is the probable opening of the river to sport, subsistence, and personal use fishing for king and pink salmon (Geoffrey Smith, NPS-SITK, personal communication 2005). Fishing for Dolly Varden is allowed in the river, including in the park, and fishermen often visit the large pool below Sawmill Creek Road before large numbers of salmon arrive. The most popular activity by far in SITK is trail use, and visitors also tour the Russian Bishop House, attend special events and educational programs, and tour the visitor center.

The Indian River and Indian River watershed extend well outside of SITK boundaries, and therefore, most of the current issues with this watershed lie outside the park (see *C1a. Water Rights and Diversions*, Figure 4). The closest neighbor to SITK is Sheldon Jackson College (SJC), which since December 1914 has had an amended certificate of appropriation (ADL 43671) to divert 30 cfs of water from the Indian River at a dam on the lower Indian River at 1.3 km (0.8 mi). Although the water is no longer used for hydropower (its intended use in 1934), SJC continues to use diverted water for their fish hatchery. The diverted water runs along a man-made stream channel that runs through the campus. The dam provides no flood attenuation because it does not have a significant storage volume (CBS 2004). Additionally, the dam promotes sediment build-up at the dam site and sediment starvation downstream, potentially producing increased channel scour downstream (CBS 2004). Storm water drainage from the college is routed into the Indian River. Above the SJC dam and 2.2 km (1.4 mi) from the mouth, the City and Borough of Sitka maintains a diversion facility. This facility functions as the city's secondary water supply facility and is used when the primary supply from Blue Lake is not available a few days each year (Dennison 1998). The city has a 1914 priority date and a certificate of appropriation (Cert. No. 658) for 3.2 cfs and 11.35 million L (2.5 million gal) of water per day from the Indian River. The Indian River Master Plan states that in the future this facility will need renovations if it is to remain working due to the river channel changing course (CBS 2004). On the west side of the Indian River, just upstream from SITK, are housing developments, including a Baranof Island Housing Authority (BIHA) subdivision, and a storm water detention and treatment facility for storm water runoff and consists of a detention pond with smaller connected basins to collect large runoff events. These basins supply primary treatment of storm water runoff by promoting sedimentation of particulates. Grass-lined ditches and swales also exist in this area and provide treatment, detention and retention of storm water via bio-filtration, controlled release, and infiltration. The upper Indian River watershed is managed by the US Forest Service. This section of the watershed has not been harvested for timber, and the US Forest Service does not divert or use the water of the Indian River.

A2. Hydrologic Information

A2a. Climatic Setting

Sitka's temperate maritime climate is characterized by heavy precipitation (annual average precipitation at SITK 245.4 cm (96 in)) and moderate temperatures with average daily temperatures ranging from -0.5 to 13 ºC (33 to 55 ºF). The early and mid-summer months of May, June, and July are drier due to high-pressure systems over the area. In contrast, the late summer and early fall months are dominated by low pressure systems that create frequent storms and supply heavy amounts of precipitation. For example, the months of April through July typically receive 7.5 to 10 cm (3 to 4 in) of rain, but September through November, the wettest months of the year, receive an average of 37.6 cm (14.8 in) each (Figure 5). Most of the precipitation within SITK is in the form of rain, but higher elevations of the Indian River watershed are supplied with a considerable amount of snow.

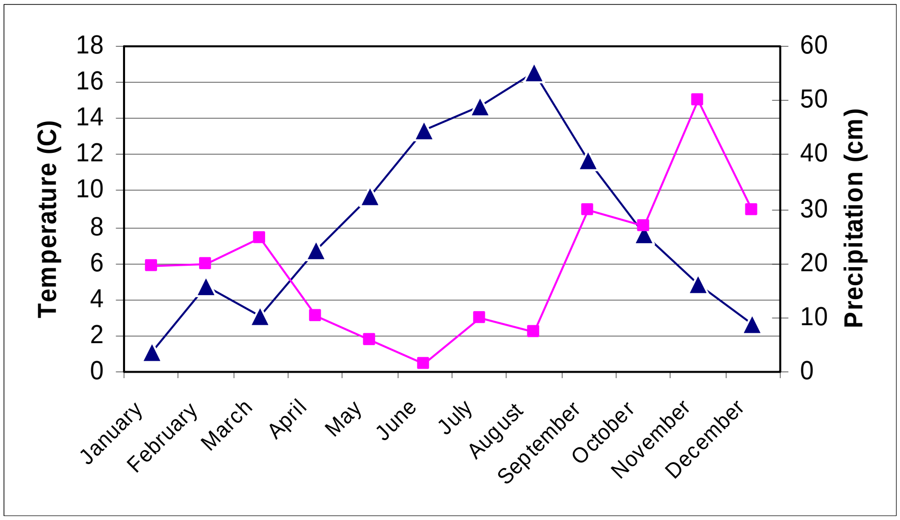

Figure 5. Average monthly temperature and precipitation for Sitka, Alaska for 2004. Triangles represent temperature (°C), and squares represent precipitation (cm). NOAA Data from http://www.arh.noaa.gov/

A2b. Hydrology

Streamflow variations in the Indian River closely track precipitation events. The basin has relatively few lakes, a high drainage density, shallow soils, steep upper slopes and a relatively small size (CBS 2004). Rainfall from Gulf of Alaska storm fronts lead to flood peaks that usually last 24 hours or less (Paustian and Hardy 1995). Two recently active USGS streamflow gages (gage #15087700 "Indian River at Sitka, AK", and gage #15087690 "Indian River near Sitka, AK") are located 310 m (1000 ft) and 1610 m (5280 ft), respectively, upstream of the SITK boundaries (Figure 4). USGS gage 15087700 has a streamflow record from October 1998- September 2003. A longer period of record is available from USGS gage #15087690, which measured flow of the Indian River from 1981 through 1993 and from 1998 through the present (Figure 6). Both gages indicate that the river's streamflow is highest in the fall, lowest during the winter/early spring and late summer, and shows a moderate increase in the late spring /early summer due to snowmelt at higher elevations (Figure 7). The average, highest, and lowest mean daily discharge values recorded by gage #15087690 are 100 cfs, 2000 cfs, and 8.6 cfs, respectively.

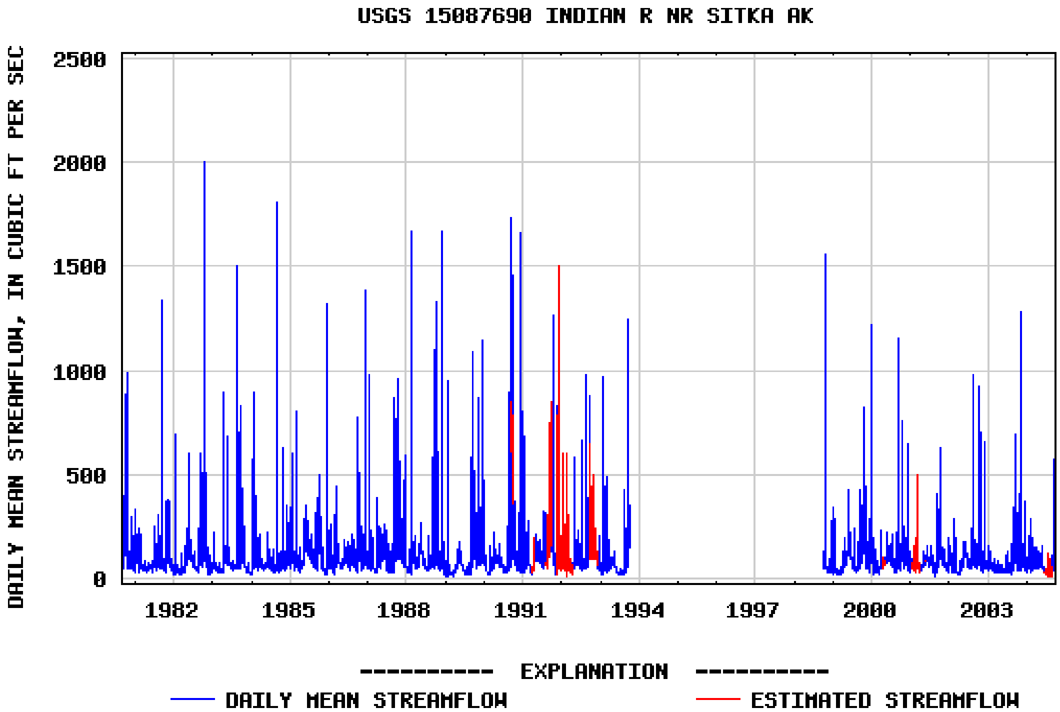

Figure 6. Daily mean streamflow for the Indian River
at USGS gage #15087690 for the full period of record: 1981-1993, and 1998-2004.

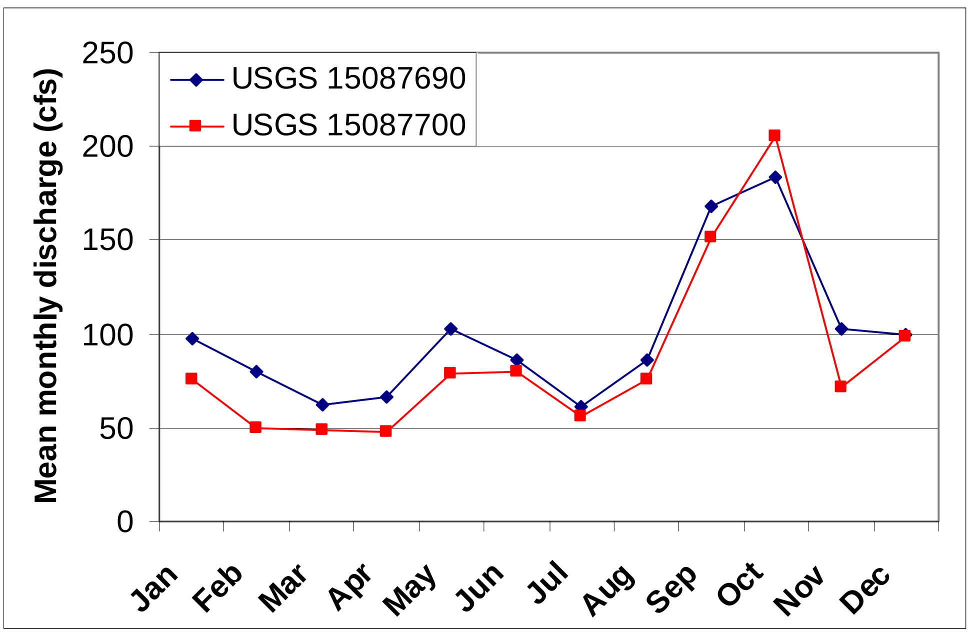

Figure 7. Monthly mean streamflow for the Indian River near Sitka, Alaska
(gage #15087690) for 1981-1993 and 1998-2004; and for the Indian River at Sitka, Alaska
(gage #15087700) for 1998-2003. Data from USGS streamflow database for Alaska
(http://waterdata.usgs.gov/ak/nwis/sw).

A2c. Water Resources

Water resources for SITK include the Indian River, its watershed, delta, estuary, floodplain channel and coastal intertidal areas (approximately 1 km (0.62 mi) long). Tides, which are some of the largest in the world, range from 4.9 m (16 ft) to -1.7 m (-5.5 ft). These tides and wave action continually shape the Indian River delta and coastline. SITK, located within Sitka Sound, is buffered from the open ocean by several offshore islands (Figure 2), and although Sitka Sound is relatively calm and well-protected, winter storms do generate significant waves. Ocean waves, which push sediment back into the river channel at the mouth of the Indian River, give the Indian River delta its asymmetrical shape.

A3. Biological Resources

A3a. Marine and Intertidal

SITK boundaries include approximately 1 km (0.62 mi) of shoreline and 20 ha (50 acres) of tidelands leased from the city of Sitka and the State of Alaska (Figures 8-9). SITK's intertidal area consists primarily of boulder and cobble substrate, which provide habitat for a diverse group of marine biota. Shallow subtidal and intertidal vegetation primarily consists of eelgrass (*Zostera marina*) in sandy areas and rockweed (*Fucus gardneri*) on medium-sized rocks (Piazza 2001). Gail Irvine (USGS) conducted intertidal monitoring in SITK in 1999, 2002 and 2003 as a part of a larger project to develop intertidal monitoring programs for coastal parks in Alaska. The protocol includes sampling vertical transects to assess percent cover of dominant species (algae and invertebrates). Data analysis of the three years of data is currently underway to assess the power of the sampling to detect change in the abundances of species, and following data analysis, the current sampling design will be revised if necessary (Gail Irvine, USGS, personal communication 2005). No reports of this monitoring activity were available for our review, although the park does have a copy of the monitoring data (Geoffrey Smith, NPS-SITK, personal communication 2005). This data will serve as important baseline to document potential future changes in intertidal areas of SITK.

ShoreZone is a project sponsored by multiple agencies and organizations that conducted aerial surveys of intertidal regions of SITK in 2004 (Figures 8-10). This project aerially surveyed intertidal and shallow subtidal areas to identify shoreline morphology, substrate, wave exposure, and biota of intertidal and nearshore habitats. This coastal habitat mapping effort produced an online database with interactive GIS layers, digital maps, aerial images and video of all of Sitka Sound with plans to map other areas of Southeast Alaska (http://mapping.fakr.noaa.gov/Website/ShoreZone/). Eelgrass (Figure 10a), coastal grasses (Figure 10b), intertidal algae (Figure 10c), barnacles (Figure 10d), and Fucus (Figure 10d) are all found in intertidal and coastal areas of SITK.


Figure 8. Tidelands in and near SITK
(photo by ShoreZone July 2004). The building furthest to the right is the SITK visitor center.


Figure 9. Estuary and delta of the Indian River
(photo by ShoreZone July 2004).

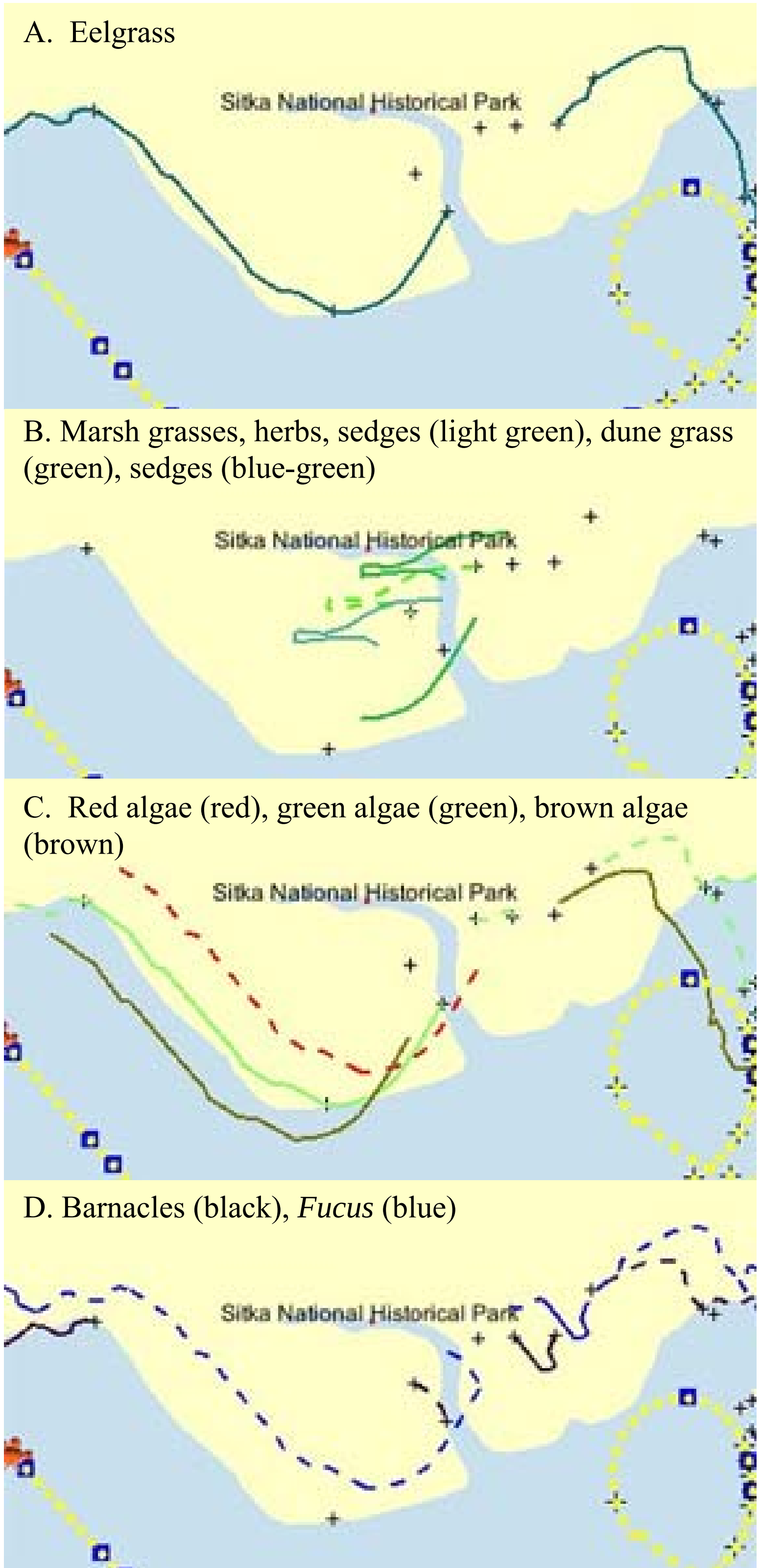

Figure 10. Shorezone maps indicating distributions of biota
Continuous lines indicate continuous distributions while dotted lines indicate patchy distributions.

Several inventories of marine and estuarine fishes within SITK conducted intertidal beach seining in the near-shore and intertidal zone (Piazza 2001, Litzow et al. 2002, Appendix 1). Litzow et al (2002) identified 25 different species of fishes in SITK, 21 of which were previously undocumented. Piazza (2001) lists 41 present and expected species of marine fishes in SITK and states that the species of fish found while seining near the estuary of the Indian River were the same species found along the SITK intertidal zone. From these two reports, a list of 53 present and expected species of marine fishes is compiled in Appendix 1.

Marine mammals do not reside within the small area encompassed by SITK, however many species were observed nearby, including humpback whales (*Megaptera novaeangliae*), Steller sea lions (*Eumetopias jubatus*), sea otters (*Enhydra lutris*), harbor seals (*Phoca vitulina*), and rarely there have been killer whales (*Orcinus orca*), gray whales (*Eschrichtius robustus*), Pacific white-sided dolphins (*Lagenorhunchus obliquidens*), harbor porpoises (*Phocoens phocoena*), Dall's porpoises (*Phocoenidae dalli*), and northern elephant seals (*Mirounga angustirostris*) (Piazza 2001).

A3b. Estuary

Paustian (1992) defined two aquatic ecological units for the section of the Indian River that runs through SITK: estuary and floodplain (Figure 8). The estuary unit extends about 183 m (600 ft) from the mouth of the Indian River to the upper part of the wetland vegetation community (Paustian 1992). The estuary is subject to daily flooding during high tides and also periodic flooding from the Indian River. The US Forest Service conducted an inventory of the Indian River estuary and found the following vegetation types (USDA Forest Service 1993): hairgrass (*Deschampsia spp.*), and hairgrass-forb plant communities in the more landward portions of the estuary, which are less frequently flooded by tides; a sedge (*Carex spp.*) community (Figure 10b) along the seaward boundary of the estuary, where tidal action is strong and salinity is higher; and thinning terrestrial vegetation and marine algal species such as rockweed (*Fucus gardneri)* (Figure 10d) at the permanently flooded zone of the estuary.

A3c. Upland

Ecological units found in SITK include the Indian River, estuary, uplifted beach meadow, uplifted beach, floodplain, stream terraces of different ages, and lowlands (USDA Forest Service 1993). Vegetation in the upland region of SITK is dominated by coastal temperate rainforest typical of Southeast Alaska, consisting of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*), with alder (*Alnus rubra*) growing near the Indian River (Nadeau and Lyons 1987). Western hemlock closed canopy forest is found on all stable landforms in the Park (NPS 2005). In areas were trees have been blown down and canopy has opened up, there is a well developed shrub understory that is dominated by devil's club (*Oplopanax horridium*) and blueberry (*Vaccinium alaskense)*. Other understory flora includes grasses, mosses and ferns, alder (*Alnus crispa*), brushy willow (*Salix* spp.) and salmonberry (*Rubus spectabilis*). Sitka spruce forest is found in unstable areas of SITK, including the floodplain on the east side of the Indian River and near the old asphalt plant site (NPS 2005). Sitka spruce is a successional community that will gradually be replaced by Western hemlock in the absence of disturbance. Red alder, which can withstand disturbance such as subsurface flooding or poor drainage, grows along both sides of the Indian River (NPS 2005). Detailed descriptions of the plant communities can be found in USDA Forest Service reports (1993 and 1994).

Old-growth forest characteristics are found in the northeast corner of SITK such as multiple canopy layers, trees of varying diameters, snags, and woody debris. One Sitka spruce in the area is up to 500 years old (NPS 2005). There are old cut stumps in the area demonstrating that selective logging may have occurred in SITK at some time in the past, however the logging history is poorly documented. Trees may have been cut by Tlingits who used fish camps in the area, or trees may have been cut in the 1800s at the time Sitka was the Russian capital and the Russians built a high, wooden stockade with three blockhouses. Almost a thousand trees were cut for the stockade; however there is no record of where these trees were cut. There is a record of the US Navy cutting in 1940 at the same time they were extracting gravel from the mouth of the River (Antonson and Hanable 1987).

Upland fauna in SITK include many species of birds and mammals, both resident and transient (Piazza 2001). A wide variety of birds pass through SITK due to the diversity of nearby habitats, including alpine, rainforest, riverine and coastal ecosystems. The intertidal and shoreline areas of SITK support large numbers of migratory waterfowl and shore birds during the spring and fall. Common mergansers (*Mergus merganser*), mallards (*Anas platyrhynchos*), spotted sandpipers (*Actitis macularia),* and great blue herons (*Ardea herodias*) are some of the resident birds that use the estuary, river, and tidal flats for foraging and protection. Sea birds such as black scoters (*Melanitta nigra*), harlequin ducks (*Histrionicus histrionicus*), greater and lesser scaup (*Aythya marila, A. affinis*), and buffleheads (*Bucephala albeola*) commonly use SITK waters, particularly in winter. Gulls (*Lanus* sp.), Northwestern crows (*Corvus caurinus*), and common ravens (*Corvus corax*) scavenge along the tidal flats and the river. Bald eagles (*Haliaeetus leucocephalus*) are also common in SITK, especially during the spring herring spawn and fall salmon runs, which provide the eagles with food from fish carcasses. Many passerine birds use SITK for breeding, as a wintering ground, or as a migratory stopover. Some passerines include pine siskins (*Carduelis pinus*), savanna sparrows, varied, hermit, and Swainson's thrushes, robins, Townsend's warblers, ruby-crowned (*Regulus calendula*) and golden-crowned kinglets (*Regulus satrapa*), belted kingfishers (*Ceryle alcyon*), American dippers (*Cinclus mexicanus*), and winter wrens (*Troglodytes troglodytes).* Appendix 2 includes a list of 171 different species of birds found in SITK (Piazza 2001).

An inventory of terrestrial mammals found in SITK lists red squirrels (*Tamiasciurus hudsonicus*) as the most common mammal (Piazza 2001). Also found are masked shrews (*Sorex cinereus*), Northern river otters (*Lutra Canadensis*), forest deer mice (*Peromyscus keeni*), voles (*Microtus oeconomus*), mink (*Mustela vison*), and Sitka blacktail deer (*Odocoileus hemionus*) (Piazza 2001). Occassionally, brown bears (*Ursus arctos*) frequent SITK when the salmon arrive in the Indian River.

A3d. Freshwater

A3d1. Freshwater Fauna

Neal et al. (2004) collected benthic macroinvertebrates in May and September 2002 at two sites on the Indian River, where USGS gages are located (Figure 3). The lower site is just upstream of the SITK boundary. Macroinvertebrates found in the Indian River (Table 1) are fairly typical for streams in Alaska. Macroinvertebrates in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), all of which were found in the Indian River, are associated with good to excellent water quality (Neal et al. 2004). Paustian and Hardy (1995) collected samples of macroinvertebrates in three locations in the Indian River, two locations in SITK, and a third upstream from SITK near the USGS gaging station. They found Ephemeroptera, Plecoptera, Trichoptera, confirming the presence of excellent water quality, and they also found Diptera (true flies) and Chironomidae. Chironomids are pollutant tolerant, and may dominate samples with degraded water quality, but are also found in areas of good water quality. Geoffrey Smith, NPS-SITK, continued collections of aquatic insects from 2002 to 2005 and generated a species list and museum collection (Appendix 3).

Table 1. Orders and Families of Indian River macroinvertebrates collected by Neal et al. (2004) and Smith (unpublished data).

Insects:	**Insects (Continued):**
Collembola	Diptera
Ephemeroptera	Ceratopogonidae
Leptophlebiidae	Simuliidae
Ephemerellidae	Tipulidae
Baetidae	Empididae
Heptageniidae	Chironomidae
Ameletidae	
Plecoptera	**Non Insects:**
Capniidae	Turbellaria
Leuctridae	Nematoda
Nemouridae	Bivalvia
Taeniopterygidae	Oligochaeta
Chloroperlidae	Lumbriculidae
Perlodidae	Naididae
Tricoptera	Enchytraeidae
Rhyacophilidae	Arachnida
Hydropsychidae	Acari
Brachycentridae	
Limnephilidae	
Phryganeidae	
Glossosomatidae	
Lepidostomatidae	
Coleoptera	
Carabidae	

The Indian River is important habitat for many anadromous fish species, including coho salmon (*Oncorhynchus kisutch*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), chinook salmon (*O. tshawytscha*), steelhead trout (*Salmo gairdneri*), and Dolly Varden (*Salvelinus malma*) and nonanadromous species such as resident rainbow trout (*Oncorhynchus mykiss)*, threespine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (*Cottus aleuticus*) (Nadeau and Lyons 1987, Brewer 2001). Anadromous fish use the river as habitat for migration, spawning, incubation of eggs, and rearing of young. From mid-July through September, adult pink and chum salmon enter the Indian River to spawn. Their fry emerge and migrate to the ocean from late February through mid-May (Nadeau and Lyons 1987). Coho salmon return to the Indian River from late September through November and spawn in the upper portion of the watershed (Nadeau and Lyons 1987). Numbers of pink salmon in the Indian River greatly outnumber the other salmon species with an estimated 1.3 million fish in the 2003 run. There is no commercial fishery for pink salmon in the Sitka area because of its low commercial value. Only the late run of coho is possibly being fished commercially, but the run is small and tracking this stock and correlating it to the different commercial salmon openings would be difficult. ADFG does not regularly monitor salmon returns on the Indian River, and there is no official escapement goal for the Indian River. The Indian River has had some spawning chinook salmon every year since at least 2000, and successful spawning has occurred because juvenile chinooks have been found in the river (Geoffrey Smith, NPS-SITK, personal communication 2005). Because the Sitka area is not known to have had any existing wild populations of chinook salmon, these fish are considered to be strays from area hatcheries (Brewer 2001). Peak salmon escapement from 1962 through 1978 consisted of only pink salmon with the exception of 30 coho salmon in 1963 (Table 2, Nadeau and Lyons 1987). There is presently a proposal to open the Indian River to salmon fishing. This proposal to the Alaska Board of Fisheries includes legal retention of up to 50 pinks and 20 kings daily (depending on whether sport, subsistence or personal use fishing) with methods that include rod and reel, dip net, fish gaff (spear), beach seine and purse seine (Geoffrey Smith, NPS-SITK, personal communication 2005). It has been recommended by Sitka's Fish and Game Advisory Committee that SITK remains closed to salmon fishing. Sport fishing for Dolly Varden does occur in the park, however this small and migratory species is only loosely managed with bag limits of 10 per day and few harvest records. Fly fisherman and kids fish for Dolly Varden in a large pool that is just inside the SITK boundary.

The maintenance of healthy salmon stocks and appropriate fish passage through coastal streams and rivers in Southeast Alaska is important not only for fisheries resources but also because spawning salmonids have significant impacts on biological resources in terrestrial and freshwater aquatic ecosystems (Gende et al. 2002). When salmon return to their natal streams to spawn, they transport marine nutrients and energy across ecosystem boundaries, and their carcasses release large quantities of "marine-derived nutrients" to freshwater and terrestrial ecosystems (Willson et al. 1998, Cederholm et al. 1999, Johnston et al. 2004). These nutrients are important to the overall health of coastal watersheds (Bryant and Everest 1998) and can greatly affect stream productivity (Wipfli et al. 1998, Chaloner and Wipfli 2002). In particular, the seasonal pulse of salmon carcasses can dramatically elevate

Table 2. Peak salmon escapement for the Indian River from 1962 through 2004 compiled from the ADFG Division of Commercial Fisheries, Integrated Fisheries Database.

YEAR	Chinook	Chum	Coho	Pink	Sockeye
1962				500	
1963			30	600	
1964				300	
1965				500	
1966				300	
1967				150	
1969				500	
1971				300	
1972				200	
1973				500	
1977				17500	
1978				2000	
1979			96	5991	
1980		125	110	2893	
1981		4	32	16000	1
1982			125	12000	
1983			55	21000	
1984			175	6000	
1985			86	11000	
1986		286	93	10000	
1987		1372	53	3000	
1988		556		1651	
1989			603		
1990		500	20	1750	
1993				800	
1994				55000	
1995				14000	
1996		500		185000	
1997				260000	
1998				66000	
1999		500		160000	
2000	50	2210		85000	
2001		1000		90000	
2002		152		68000	
2003				270000	
2004		2215		73000	

streamwater nutrients levels (Mitchell and Lamberti 2005), thereby affecting primary and secondary productivity in receiving streams. In addition, carcasses that end up in the riparian zone as a result of changes in stream discharge or bear activity provide a substantial input of nutrients such as nitrogen and phosphorus to riparian soils (Gende et al. in prep). These nutrients can be rapidly assimilated by microbial communities and vegetation in the riparian environment (Bilby et al 1996) and have been hypothesized to increase the growth rate of trees in the riparian forest (Helfield and Naiman 2001). These findings highlight the ecological importance of salmon coastal ecosystems and suggest that fisheries management decisions related to salmon have the potential to affect terrestrial biological resources within SITK.

A3d2. Freshwater Benthic Algae

Algae are important primary producers and food source and can be indicators of physical and chemical disturbance of stream habitats. An extensive collection and summary of benthic algae documents the species composition and cell density for all algae of the Indian River (Neal et al. 2004). Samples were taken at two sites on the Indian River, neither of which is inside the boundaries of SITK. The upper site is located well over 1.6 km (1 mi) upriver from SITK at USGS Gage station 15087690. The second site is located at USGS Gage number 15087700, which is just downstream of both the CBS and SJC diversions and immediately upstream of the SITK boundary. Thirty five species were identified. Algal communities were dominated by pinnate diatoms (microscopic, single-celled organisms), green algae (*Spirogyra* sp.), and blue-green algae (*Pseudanabaena* sp.). The species composition of these samples indicates that the quality of the Indian River, at least where the samples were taken, was good to excellent (Neal et al. 2004).

B. Water Resources Assessment

B1. Water Quality

B1a. Indian River

In cooperation with the NPS, the USGS conducted a water quality analysis of the Indian River in both the undeveloped upper part of the watershed and in the developed lower part of the watershed (Neal et al. 2004). Table 3 provides a summary of the data presented in Neal et al. (2004). Overall, they found that the water of the Indian River was of high quality in both upstream and downstream areas. Physical and chemical parameters such as specific conductance, pH, water temperature, dissolved oxygen, major ions, nutrients, dissolved organic carbon, and suspended sediment were measured to establish a water quality baseline for the river. Water quality parameters such as pH, water temperature, and dissolved oxygen were within acceptable ranges for fish survival. The pH of the Indian River during this study period ranged from 6.5 to 7.7 for the upper site and 6.5 to 8.1 for the lower site. Water temperature for the upper site ranged from 0.5 °C (33 °F) on February 11, 2001 to 10.5 °C (51 °F) on August 12, 2001. Water temperature for the lower site ranged from 0.0 °C (0 °F) on April 6, 2001 to 10.5 °C (51 °F) on August 12, 2001. Water temperature is important for such biological processes as oxygen solubility, fish metabolism, and growth rates. Dissolved oxygen concentrations were similar in both upstream and downstream sites and varied between 11.2 and 14.1 mg/l. This level of dissolved oxygen is adequate to support populations of salmonids, which require well-oxygenated water at every stage in their life history. Alkalinity measurements showed low buffering capacity, ranging from 10 to 15 mg/l $CaCO_3$. Concentrations of dissolved ions and nutrients were generally low in both upstream and downstream areas. Suspended sediment, which may limit the amount of sunlight and thus productivity in the river, was also low, ranging from 0 to 4 mg/l, with little variation upstream and downstream, although sediment load increased during high flow events. The analysis of benthic algae indicated that water quality of the Indian River where the samples were taken was good to excellent (see *A3d2.Freshwater Benthic Algae* above).

The Department of Environmental Conservation does not list the Indian River or any area nearby that could affect the Indian River as a contaminated site. This watershed is considered to be healthy and is relatively pristine, and does not violate any of the criteria for Alaska's water quality standards. Water quality standards for the state of Alaska are summarized in Appendix 4.

Water quality data for the Indian River within SITK boundaries were collected in 1996 and 1997 by Shannon & Wilson Inc. as a part of a Phase II Site Assessment of the Indian River Asphalt Plant Site (Tables 4 and 5, NPS 1998). One site was on the east bank at the mouth of the Indian River, the site of the old asphalt plant. The second site was located on the west side of the Indian River footbridge, which served as a control with which to compare data collected at the asphalt plant site. No violations to EPA's water quality criteria were observed in these samples. SITK personnel continue to collect water samples to monitor this site (see section B3a2), although the more recent data have not yet been compiled into a report.

Table 3. Summary statistics for water quality data
collected between 01/04/01 and 09/20/02 from the Indian River. Data from Neal et al. (2004).

	Specific Conductance (mS/cm)	pH	Water Temp (ºC)	Diss. Oxygen (mg/L)	Discharge (ft3/s)	Alkalinity (mg/L as CaCO3)	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
near Sitka										
median	42	7.2	5.0	12.2	78	14	5.0	0.5	1.9	0.12
mean	43	7.2	5.1	12.3	92	14	5.2	0.5	1.9	0.13
min	36	6.5	1.5	11.3	16	11	4.5	0.5	1.7	0.10
max	53	7.7	7.5	14.1	270	17	6.3	0.7	2.3	0.18
stdev	6	0.4	2.3	0.8	69	2	0.6	0.1	0.2	0.02
n	11	11.0	9.0	9.0	11	9	10.0	10.0	10.0	8.00
at Sitka										
median	41	7.3	5.3	12.0	75	14	5.0	0.6	2.0	0.15
mean	42	7.3	5.1	12.2	78	13	5.1	0.6	2.1	0.23
min	36	6.5	2.0	11.4	9	10	4.5	0.5	1.8	0.10
max	53	8.1	8.5	14.1	222	15	6.1	0.7	2.4	0.82
stdev	5	0.4	2.5	0.8	60	2	0.6	0.1	0.2	0.23
n	10	11	10	9	11	9	10	10	10	9

	Bicarbonate mg/L	Sulfate mg/L	Chloride mg/L	Silica mg/L	Diss. solids mg/L	Nitrogen (NO_2+NO_3) mg/L	Diss. organic C mg/L
near Sitka							
median	17	1.6	3.4	3.2	28.0	0.10	1.2
mean	17	1.6	3.1	3.2	27.6	0.09	1.3
min	14	1.4	2.1	2.7	22.0	0.03	0.5
max	20	1.9	4.0	4.1	34.0	0.15	3.2
stdev	2	0.2	0.8	0.4	3.8	0.04	0.8
n	9	10.0	10.0	10.0	9.0	10.00	10.0
at Sitka							
median	17	1.7	1.7	3.4	30.0	0.10	1.4

mean	16	1.7	1.7	3.5	27.9	0.10	1.6
min	12	1.3	1.3	2.9	19.0	0.03	0.7
max	19	2.2	2.2	4.4	34.0	0.15	3.3
stdev	3	0.3	0.3	0.5	5.4	0.03	0.9
n	9	10	10	10	9	9	10

Below detection level:

Nitrogen nitrite, dissolved (as N) (<0.002 mg/L)
Nitrogen, ammonia, dissolved (as N) (<0.015 mg/L)
Nitrogen ammonia + organic, total (as N) (<0.08 mg/L)
Nitrogen ammonia + organic, dissolved (as N) (<0.10 mg/L)
Phosphorus, total (<0.004 mg/L)
Phosphorus, dissolved (<0.004)
Phosphorus, ortho dissolved (as P) (<0.007)
Particulate organic carbon (as C) (<0.1)

Table 4. Water quality inventory for site at east bank at the mouth of the Indian River for 1996 and 1997. Water samples collected by Shannon & Wilson as a part of Phase II Site Assessment for the Indian River Asphalt Plant. Data taken from NPS (1998).

Parameter	**Period of Record**	**Obs.**	**Median**	**Mean**	**Maximum**	**Minimum**	**Std. Dev.**
Temperature, Water (°C)	06/27/96-07/24/97	4	10.3	10.15	11.	9.	1.012
Specific Conductance, Field (UMHOS/CM@25C)	06/27/96-07/24/97	2	1555.	1555.	2600.	510.	1477.853
pH, Field, Standard Units SU	06/27/96-07/24/97	2	7.015	7.015	7.05	6.98	0.049
Converted pH, Field, Standard Units	06/27/96-07/24/97	2	7.014	7.014	7.05	6.98	0.05
Micro Equivalents/liter of H+ Computed from pH	06/27/96-07/24/97	2	0.097	0.097	0.105	00.89	0.011
Residue, Total Nonfiltrable (mg/L)	06/27/96-07/24/97	4	4.	6.625	18.	0.5	7.804
Hardness, Total (mg/L as CACO3)	06/27/96-07/24/97	4	358.	605.75	1660.	47.	724.727
Iron, Total (UG/L as FE)	06/27/96-07/24/97	4	258.5	523.5	1510.	67.	676.02
Iron, Dissolved (UG/L as FE)	06/27/96-07/24/97	2	25.	25.	30.	20.	7.071
Lead, Dissolved (UG/L as PB)	06/27/96-07/24/97	4**	0.1	0.1	0.1	0.1	0.
Lead, Total (UB/L as PB)	06/27/96-07/24/97	4**	0.1	0.1	0.1	0.1	0.
Hydrocarbons, Aqueous, Total UG/L	06/27/96-07/24/97	4**	792.5	1190.	2700.	475.	1048.245
Mercury, Total (UG/L as HG)	06/27/96-07/24/97	4**	0.1	0.1	0.1	0.1	0.

** - Computed with 50% or more of the total observations as values that were half the detection limit.

Table 5. Water quality inventory for site at west side of the Indian River at the footbridge for 1996 and 1997.
Source same as Table 4.

Parameter	Period of Record	Obs.	Median	Mean	Maximum	Minimum	Std. Dev.
Temperature, Water (°C)	06/27/96-07/24/97	2	9.4	9.4	9.8	9.	0.566
Specific Conductance, Field (UMHOS/CM@25C)	06/27/96-07/24/97	1	34.	34.	34.	34.	0.
pH, Field, Standard Units SU	06/27/96-07/24/97	1	7.06	7.06	7.06	7.06	0.
Converted pH, Field, Standard Units	06/27/96-07/24/97	1	7.06	7.06	7.06	7.06	0.
Micro Equivalents/liter of H+ Computed from pH	06/27/96-07/24/97	1	0.087	0.087	0.087	0.087	0.
Residue, Total Nonfiltrable (mg/L)	06/27/96-07/24/97	2**	9.25	9.25	18.	0.5	12.374
Hardness, Total (mg/L as CACO3)	06/27/96-07/24/97	2	15.	15.	18.	12.	4.243
Iron, Total (UG/L as FE)	06/27/96-07/24/97	2	773.5	773.5	1540.	7.	1083.995
Iron, Dissolved (UG/L as FE)	06/27/96-07/24/97	1	50.	50.	50.	50.	0.
Lead, Dissolved (UG/L as PB)	06/27/96-07/24/97	2**	0.1	0.1	0.1	0.1	0.
Lead, Total (UB/L as PB)	06/27/96-07/24/97	2**	0.1	0.1	0.1	0.1	0.
Hydrocarbons, Aqueous, Total UG/L	06/27/96-07/24/97	2**	3487.5	3487.5	6500.	475.	4260.318
Mercury, Total (UG/L as HG)	06/27/96-07/24/97	2**	0.1	0.1	0.1	0.1	0.

** - Computed with 50% or more of the total observations as values that were half the detection limit.

B1b. Precipitation

The chemistry of precipitation is not currently being monitored in SITK; however, a new National Atmospheric Deposition Program (NADP) site was established in southeast Alaska 20 km (12 miles) north of Juneau in 2004. The NADP is a nationwide network that contains more than 200 precipitation chemistry monitoring sites in the continental United States, Alaska, Puerto Rico, and the Virgin Islands. There are 4 NADP sites in Alaska, two of which are administered by the National Park Service (Denali and Gates of the Arctic). The NADP site near Juneau (NADP #AK02) is the closest station to SITK and is likely representative of precipitation received there. Preliminary data from the Juneau NADP site show a predominance of marine aerosols (chlorine, sulfate, and sodium) and very low levels of nitrogen (ammonium and nitrate) compared to sites in the contiguous United States (E. Hood, unpublished data). Data on precipitation chemistry in Alaska are available through the NADP website located at: http://nadp.sws.uiuc.edu/sites/ntnmap.asp?

B1c. Sitka Sound

Water quality in Sitka Sound appears to be high, however little monitoring has been conducted. The CBS has monitored water quality in receiving waters of the wastewater facility in accordance with their NPDES permit since the 1980s (Mark Ojala, CBS, personal communication 2006). Our review of monitoring summary reports from 1997, 1999, and 2002-2005 revealed that the wastewater facility does not exceed state water quality standards or permit limitations, and water quality in Sitka Sound, even within close proximity to wastewater discharge, is good (CBS Internal Memoranda 1998, 1999, 2002, 2003, 2004, 2005, 2006). Fecal coliform, dissolved oxygen, salinity, temperature, secchi disk depth, whole effluent toxicity, and the benthic biological community were monitored, and all were within permit and water quality limitations (see one exception below). The effects of discharge are considered negligible on the benthic community. On only one occasion (August 25, 2005) did fecal coliform levels exceed permit levels, and that anomaly was attributed to the presence of a large cruise ship in the vicinity of the sampling station. The effects of large cruise ships on Sitka Sound water quality are largely unknown. ADEC conducts cruise ship monitoring (see below).

The Beach Environmental Assessment and Coastal Health (BEACH) Act, signed into law October 2000, states that coastal water monitoring should take place in areas used recreationally, and especially in areas that are close to a pollution source (Environmental Protection Agency 2005). Through surveys and community visits, the Alaska BEACH Grant Program has ranked public use beaches by their potential risk of being exposed to marine water polluted by fecal contamination by a variety of sources. Potential sources of fecal bacteria could be sewage, storm water runoff, boating waste, malfunctioning septic systems, animal waste, and other sources. At this time, beaches in Sitka have been ranked low risk by the Alaska BEACH Grant Program (Barbara Smith, ADEC, personal communication 2005). The coastal area is used recreationally throughout the year, although not frequently for swimming. People walk the beach, explore the exposed intertidal zone, and in some cases scuba dive directly off the SITK coast (Geoffrey Smith, NPS-SITK, personal communication 2005).

Water quality in marine waters was recently surveyed by the Environmental Monitoring and Assessment Program (EMAP), which sampled throughout Southeast Alaska (Figure 10) in 2004 including two stations in Sitka Sound. At 40 stations, physical properties (conductivity, temperature, salinity, pH, dissolved oxygen, chlorophyll fluorescence), water (nutrients, chlorophyll a, and total suspended solids), sediment (contaminants, infauna), and benthic fish and invertebrates (trawl) were sampled. At 11 additional stations, water was sampled for bacteria as a part of the ADEC cruise ship program. Data from this sampling effort was not available at the time of publication of this report. The final report for Southeast EMAP is expected to be released in 2007 from ADEC.

B2. Water Quality Impairments

Sediment chemistry data can be evaluated through the use of numerical sediment-quality guidelines (SQGs) to estimate the potential for adverse effects to biota. MacDonald et al. (2000) compiled the various published SQGs to develop a list of consensus-based SQGs for 28 chemicals of concern (i.e., metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and pesticides) in freshwater sediments. For each contaminant of concern, two values were developed: a threshold effect concentration (TEC), the concentration of contaminants below which the incidence of toxicity to sediment-dwelling organisms was not expected to occur, and a probable effect concentration (PEC), the concentration of contaminants above which the incidence of toxicity to sediment-dwelling organisms was expected to occur frequently. Neal et al. (2004) compared concentrations of trace elements sampled at upstream (USGS gage 15087690) and downstream areas (USGS gage 15087700) of the Indian River and found that bed sediment concentrations of arsenic, chromium, copper, nickel, and zinc exceeded the TEC, and concentrations of arsenic, chromium, and nickel exceeded the PEC (Table 6). However, Neal et al. (2004) add that due to the Indian River bed sediments having high concentrations of toxicity-mitigating organic carbon, the combined effects of multiple contaminants for both upstream and downstream sites were low

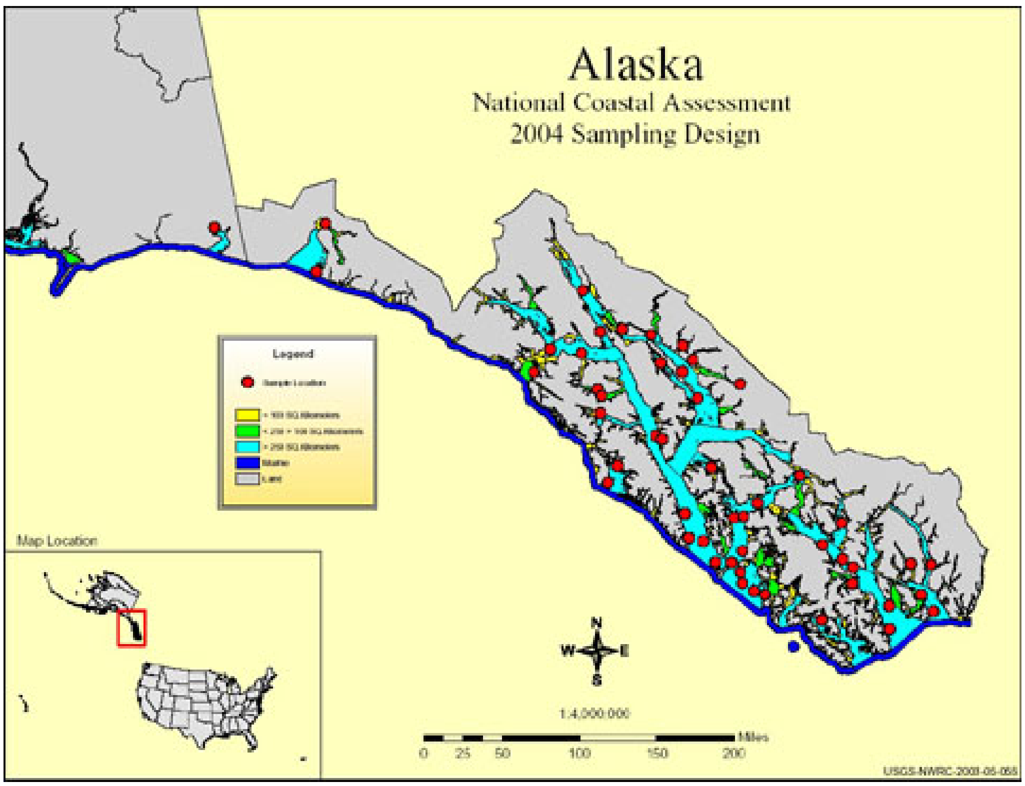

Figure 11. Sites sampled by EMAP in Southeast Alaska in 2004
From http://www.dec.state.ak.us/water/wqamp/emap_se.htm

Table 6. Concentrations of selected trace elements from bed sediments from the Indian River compared with TEC and PEC values (Neal et al. 2004). Values in micrograms per gram.

Trace element	Upstream site (Gage 15087690)	Downstream site (Gage 15087700)	Threshold Effect Concentration (TEC)	Probable Effect Concentration (PEC)
Arsenic	47	33	9.8	33
Chromium	180	180	43.4	111
Copper	100	84	31.6	149
Nickel	72	68	22.7	48.6
Zinc	140	140	121	459

(Neal et al. 2004). Trace elements found in the streambed are similar at both sites, with some having slightly lower concentrations at the downstream site. This suggests these elements originated from natural sources with no indication of anthropogenic influences at the downstream site (Neal et al. 2004)

B3. Sources of Pollutants

B3a. Point Sources

B3a1. Asphalt Site

The "Indian River Asphalt Site" is near the mouth of the Indian River on the northeast bank. It is a potential pollution point source to the Indian River within SITK. This 0.3 ha (0.75 acre) site contained an asphalt plant from 1957-1961 (see *A1b. Human Utilization*) (Shannon & Wilson 1995). Soils from the site, contaminated with weathered diesel and asphalt-range material, have intermittently been released to the marine environment since 1990 and probably much earlier (Shannon & Wilson 1995). There have also been reports of significant erosion occurring along this bank in 1993 and 1994 (Shannon & Wilson 1995). Sampling at the site in 1994 did not find significant levels of volatile or aromatic hydrocarbons or metals that significantly exceed background levels, with the exception of one sample of lead (Shannon & Wilson 1995). The groundwater at this site was not sampled for contamination, but based on sampling in test pits, it is probable that the groundwater is contaminated to some extent by dissolved hydrocarbons (Shannon & Wilson 1995). However, because the groundwater at this site is brackish, it is not a source of drinking water and therefore not a human health concern. Because contaminants are released only sporadically, usually when the bank erodes due to a storm event, it is unlikely that repeated human contact with these soils during release events would occur or that contaminants are accumulating in the marine environment. The bank will continue to erode, which will allow greater levels of contamination to be exposed at some point in the future. At the recommendation of Shannon & Wilson (1995), the NPS presently is taking no remedial action and is allowing the bank erode naturally. The NPS has implemented a monitoring program for this site. Site monitoring of water quality, soil contamination, and bank erosion continues on an annual or biannual basis. No unusual contaminants have been detected in the last four years (2002-2005), though asphalt chunks and metal continue to be exposed as the bank erodes (Geoffrey Smith, NPS-SITK, personal communication 2005).

B3a2. Sheldon Jackson College drainage

A possible point source of pollutants is drainage from Sheldon Jackson College. Drainage ditches run from the college property into the Indian River. Maintenance on college property is often done by volunteers, and there is no record of what discharge from the college grounds may contain. Three drainages that originate on Sheldon Jackson College property cross SITK property and enter the Indian River within SITK. One is a natural tributary, the second is an Indian River diversion stream that travels through campus and is returned to the river inside the park, and the third collects surface drainage around a housing complex (Geoffrey Smith, NPS-SITK, personal communication 2005). One violation of state standards for fecal coliform occurred on 9/10/2001 in a sample from the ditch near the housing complex. The fecal coliform sample had a concentration of 300 MPN/100 mL, which is several-fold higher than the allowable mean concentrations of fecal coliform over 30-day periods for all the various water supply uses (including drinking water, aquaculture, industrial and recreational). This appears to be an isolated event as no violations were found during subsequent sampling events at that site (n=4), and SITK has since put in a culvert and filled in the ditch. SITK continues to monitor water quality for pH, temperature, metals, hydrocarbons, sediments, and other water quality parameters on the college property up to twice per year and has found no unusual results to date other than the single fecal coliform violation (Geoffrey Smith, NPS-SITK, personal communication 2005). Data from SITK park initiated monitoring have not been compiled into a report.

B3a3. Petroleum spills

Petroleum poses a range of environmental risks when released into the environment, whether as catastrophic spills or chronic discharges. In addition to physical impacts of large spills, the toxicity of many individual compounds contained in petroleum is significant, and even small releases can kill or damage organisms. Petroleum can enter SITK waters through the following mechanisms:

- Leaks, spills, or discharge of bilge or ballast water.
- Discharge from a two-stroke engine.
- Accidental release through a vessel grounding or collision.

The impact of a release of petroleum from any of the above mechanisms would depend on the size of the spill, the location of the spill, the type of petroleum product, and the effectiveness of the response to the spill. SITK has approximately 1 km of coastline and 50 acres of intertidal along Sitka Sound, an area that has significant marine vessel traffic from commercial fishing vessels, subsistence and sport fishing vessels, other pleasure craft, and cruise ships.

Geographic Response Strategies (GRS), created through DEC and other agencies, are spill response plans tailored to protect a specific sensitive area from oil impacts following a marine vessel spill. There is a GRS for several selected sites along the Sitka coastline, and one of these is at the mouth of the Indian River (site SE05-05) (Figure 11). These sites were selected based on the criteria of environmental sensitivity set forth in the Southeast Alaska Subarea Plan (ADEC 2005).

B3a4. NPDES permits

There is only one National Pollution Discharge Elimination System (NPDES) permit in the Sitka area issued by the EPA (EPA 2001). The permit allows the Sitka Wastewater Treatment Plant to discharge up to 5.3 million gallons per day into the Middle Channel of Sitka Sound at a depth of 85 feet below mean low water level. The permit has been effective since 12/31/01 and is valid through 1/2/07. *See B1c. Water Quality Sitka Sound* for more information on water quality monitoring in accordance with this permit.

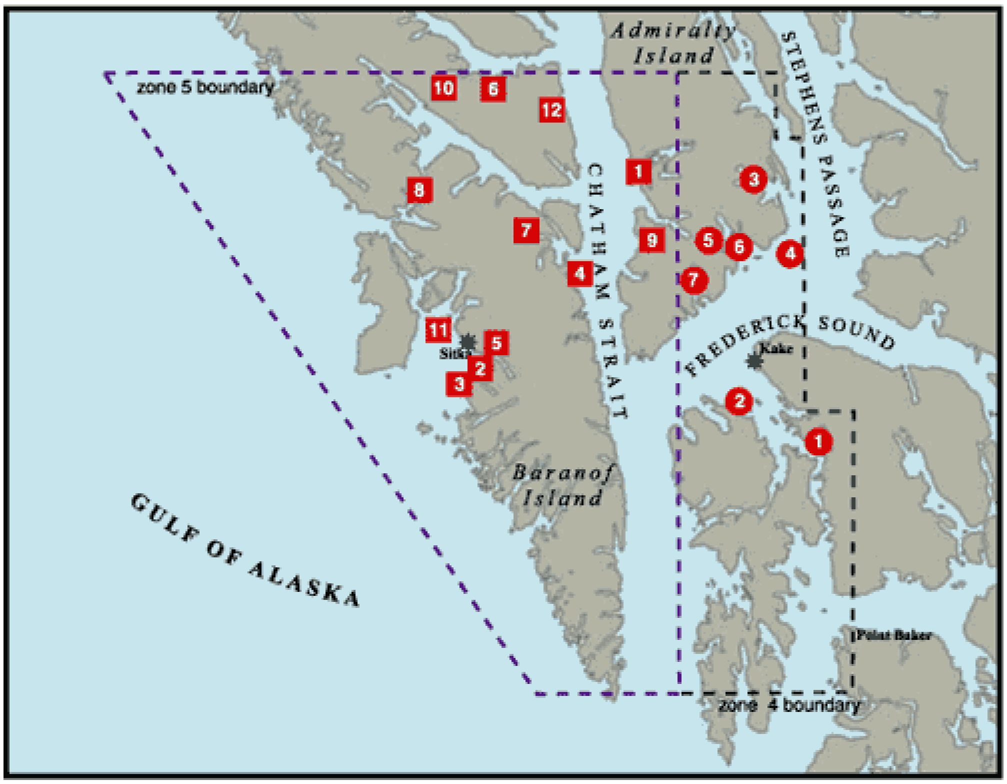

Figure 12. Geographic Response Strategy sites for zones 4 and 5 of Southeast Alaska showing site 5 in zone 5 at the mouth of the Indian River. Source: ADEC 2005.

B3b. Non Point Sources

B3b1. Urbanization

Urbanization and ongoing development pose a threat to water quality and habitat in the Indian River within and above SITK. Urban development can dramatically alter the hydrology of impacted rivers and streams. Impervious surfaces such as roads and parking lots have little or no storage, resulting in an increase in surface runoff compared to native ground cover, which can absorb rainfall and snowmelt via infiltration. Previous research in the Pacific Northwest has shown that without the placement of effective riparian buffers, biological integrity and habitat condition decline rapidly in urban watersheds that have greater than 5% impervious cover (May et al. 1997, Ourso 2001). The primary water quality concern associated urban development is runoff from urban surfaces (Makepeace et al. 1995). In urban environments, motor vehicles act as a source of oil and grease, hydrocarbons, and heavy metals, all of which can be transported into surface waters during storm events. Sediment loading from soil erosion, construction sites and road sanding as well as nutrient loading (nitrates and phosphates) from fertilizers and septic systems are also common pollution problems associated with urban runoff. In addition, urban development impacts in-stream habitat by decreasing the recruitment of large woody debris, increasing bank erosion and stream temperatures, and decreasing stream baseflows.

Past studies of water quality and sediment transport in the Indian River suggest that urban runoff is not detectably affecting water quality (Neal et al. 2004). However, because water quality testing has been rare, it is possible that polluting conditions have occurred infrequently enough to be missed by sampling events. The species composition and density of algae and macroinvertebrates support the conclusion that this system is generally unimpaired (see *A3d.Freshwater Habitat*). However, future residential developments, road improvements, and road runoff may result in greater potential for pollutants (see *C2.Development Trends*). Additionally, the extent to which urbanization has affected salmonid rearing habitat is not known. Rearing habitat can be reduced as a result of decreased quantity and quality of large woody debris as well as increased sediment loadings. Moreover, increased stream temperatures associated with riparian buffer removal and decreased groundwater recharge can also harm incubating and rearing salmonids (Gregory and Bisson, 1997).

B3b2. Atmospherically-derived contaminants

Evidence is mounting that Alaska and other arctic and subarctic regions are not immune to contamination by chemicals that are able to travel far from their original sources (Fitzgerald et al. 1998, Heiman et al. 2000, AMAP 2002, AMAP 2004). In fact, some of these chemicals not only can reach Alaska from distant sources in temperate and tropical regions, but they have a tendency to accumulate in Alaska. Entering the food chain, they biomagnify as they pass up trophic levels, and pose serious threats to the health of marine, freshwater, and terrestrial organisms (EPA 2002). Few studies on contaminants in Southeast Alaska exist; however, these few studies indicate that the region is accumulating many potentially toxic chemicals imported from afar.

Mercury and a group of chemicals known as Persistent Organic Pollutants (POPs) are the 2 major subjects of concern for Alaska in terms of global contaminants. Mercury, a strongly toxic heavy metal, is emitted primarily by fossil fuel burning (Pacyna and Pacyna 2002). Anthropogenic mercury deposition to Alaska appears to be similar in magnitude to that in temperate latitudes (Fitzgerald et al. 2005). POPs comprise a long list of highly toxic and very stable organic compounds such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), dioxins, furans, and chlordane that are used as pesticides, industrial chemicals and industrial waste products (EPA 2002). The vast majority of them are carried to Alaska via long-range atmospheric pathways (Strand and Hov 1996, Wania et al. 1999, Schroeder and Munthe 1988). Mercury and POPs in northern latitudes show significant concentration increases over the last few decades, and these trends are reflected in the extraordinarily high concentrations of some of these chemicals in the bodies of otters, whales, seals, bears, eagles, and indigenous peoples who rely on subsistence harvests (AMAP 2002, 2004).

Although Hg and POPs have not been studied in SITK specifically, several studies within Southeast Alaska, including within Sitka Sound itself, indicate the region as a whole is being impacted by these contaminants. One study on contaminants in sea bird eggs showed that concentrations of POPs in common murre eggs from two islands in the Gulf of Alaska were significantly higher than in eggs from three colonies in the Bering Sea (Kucklick et al. 2002; Vander Pol et al. 2002a; Vander Pol et al. 2002b). Eggs from St. Lazaria (in Sitka Sound) had higher concentrations of SPCBs (sum of 46 congeners of PCBs) than eggs from any other Alaskan colonies (Kucklick et al. 2002; Vander Pol et al. 2002a; Vander Pol et al. 2002b). Geographic differences in POP concentrations are not understood, but may be products of global wind and ocean current patterns that result from variable deposition characteristics within Alaska. Mercury was also evaluated in the seabird egg studies (Christopher et al. 2002, Davis et al. 2004, Day et al. 2004), which indicated that mercury pollution may also be more of a concern in Southeast Alaska compared to other regions of Alaska. Murre eggs collected from islands in the Gulf of Alaska had mercury concentrations that were several-fold higher than in eggs from islands in the Bering Sea, and the highest concentrations of mercury were again from St Lazaria Island in Sitka Sound (Christopher et al. 2002). The authors of these studies speculate that higher mercury concentrations in the Gulf of Alaska sites may be due to the relatively warm temperatures and abundance of organic matter in forested areas and wetlands in Southeast Alaska. Wetlands and other organic-rich, saturated areas are particularly efficient MeHg generators because their biogeochemical conditions are highly favorable to bacterial methylation (by sulfate-reducing bacteria) of Hg, the main process that converts inorganic Hg (mainly Hg^{2+}) to toxic MeHg. A study of dated sediment cores collected at three lakes in nearby Glacier Bay National Park (GLBA) suggests that modern Hg accumulation rates in sediments are approximately double preindustrial accumulation rates (Engstrom and Swain 1997). Additionally, Hg deposition in GLBA did not show the recent declines (since the1960s) observed at sites in the continental U.S. where regional mercury emissions have been reduced. These results suggest that Southeast Alaska is being affected by mercury emissions from remote sources (e.g. in Asia), that are steadily increasing their output (Pacyna and Pacyna 2002a).

The outlook is mixed for future deposition of POPs and Hg in Southeast Alaska. The Stockholm Convention, a global initiative to phase out 12 of the most dangerous POPs should reduce the threat that these pollutants pose to ecosystems such as those within SITK. However, numerous other forms of POPs are still being manufactured and released into the environment in large quantities with unknown consequences (Giles, 2004). While mercury emissions in the USA have decreased in recent decades, global emissions continue to increase, particularly in Asia, a major source region for prevailing weather patterns that feed the northwest coast of North America (Pacyna and Pacyna 2002b). As a result, Southeast Alaska is predicted to be impacted by rising mercury contributions for decades to come. In sum, the limited studies to date strongly suggest that the threats posed by mercury and POPs to ecosystems in Southeast Alaska are significant and deserve further evaluation and monitoring.

C. Other Areas of Concern

C1. Water Quantity

C1a. Water Rights and Diversions

Under the Alaska Water Use Act, a water right is a legal right to use surface water or groundwater and allows a specific amount of water from a water source to be diverted or withdrawn for a specific purpose. The NPS has an implied federal reserve water right on the Indian River. Sheldon Jackson College (SJC), the City and Borough of Sitka (CBS), and the Alaska Department of Fish and Game (ADFG) also hold water rights on the Indian River (Table 7).

Table 7. Water rights within the Indian River watershed (Bill Hansen, NPS WRD Water Rights Branch, personal communication 2006)

Water Right Holder	State File Number	Priority Date/s	Beneficial Use	Diversion Rate (cubic ft/sec)	Volume Limitation (acre-feet)	Period of Use
Sitka National Historic Park	None (Federal Reserved Right)	June 21,1890 March 23, 1910	Park Purposes	Unquantified	Unquantified	Jan 1 to Dec 31
Sheldon Jackson College	Cert. No. 657	Dec. 31, 1914	Hydro Power Generation and Fish Hatchery	30.0	21,721.15	Jan 1 to Dec 31
City and Borough of Sitka	Cert. No. 658	1914	Municipal Water Supply	3.88	None	Jan 1 to Dec 31
City and Borough of Sitka	ADL 101686*	Sept. 23, 1980	Municipal Water Supply	5.42	4.0	Jan 1 to Dec 31
Sheldon Jackson College	LAS 159**	Nov. 29,1982	Fish Hatchery	4.96	None	Jan 1 to Dec 31
Alaska Dept. of Fish and Game	Cert. of Reservation LAS 12236	Jan. 12, 1989	Spawning, Incubation and Rearing of Salmon	Variable Flow by Season (35 to 101)	None	Dec 1 to Nov 30

*Permit Inactive, **Application Closed on Oct. 31, 1996

The NPS filed an application for a State Declaration of Appropriation for an existing water right in the Indian River with the State of Alaska in 1967 (Nadeau and Lyons 1987). The NPS claimed a priority date of 1890 under the Federal Reserved Water Rights Doctrine which was the date when the park was first set aside as a federal reserve (Nadeau and Lyons 1987). The purpose of the right was to maintain instream flows within SITK for fish habitat, recreational, and interpretive purposes. The application was not granted by the Alaska Department of Natural Resources (ADNR). However, the park continues negotiations with SJC, the State, and other stake holders to secure and maintain instream flows to protect aquatic life and a healthy ecosystem in the Indian River (Geoffrey Smith, NPS-SITK, personal communication 2005).

SJC maintains a diversion flume 1.3 km (0.8 mi) upstream from the mouth of the river. The college originally had a 1914 right to divert 50 cfs for hydro power generation. They received an amended certificate of appropriation in1996 for 30 cfs for hydro power generation and fish hatchery purposes. SJC has not used water for hydro power production since 1988, but continues to divert water through the campus to the fish hatchery.

CBS maintains a diversion facility 2.25 km (1.4 mi) from the mouth of the river. The city has a certificate of appropriation for 3.9 cfs, with a 1914 priority date for municipal water supply purposes. In addition, the city filed a water right application in 1980 for 5.4 cfs for municipal water supply purposes. The city diverts and uses water from the Indian River as a backup potable water supply when the primary supply from Blue Lake is unavailable during systems maintenance. This generally only occurs a few days each year.

ADFG has a certificate of reservation, with a priority date of 1989, for instream flows for spawning, incubation, and rearing of salmon. Their water right reserves variable flows from the mouth of the Indian River upstream to river km 4 (mile 2.5) for different periods of the year. Because the ADFG water right has a later priority date, it is CBS and SJC water rights, and they do not have to reduce their diversions when the instream flow for ADFG is unavailable. Nadeau and Lyons (1987) give a more detailed description of the water rights of the Indian River.

C1b. Instream Flow

A major area of concern with the Indian River is the maintenance of adequate instream flows. Low flows in the river may occur naturally or as the result of diversions by CBS and SJC. Natural low flow events occur in the winter, when and the Indian River ices and during sustained high-pressure weather systems that produce relatively dry climatic conditions in the region. Low flow conditions can occur in any month of the year, but they are less likely to occur in the late spring, when snowmelt contributes to the streamflow. Low flow negatively affects suitable habitat for salmon spawning, incubation, and rearing (Nadeau and Lyons 1987). In fact, the "…occurrence of major low-flow events during the incubation or intergravel phase of life is one of the most limiting flow-related factors to salmon production in Southeast Alaska" (Nadeau and Lyons 1987). Climate changes that affect the amount or timing of precipitation may also affect instream flow (see *C7. Climate Change* below).

C2. Development Trends

To date, development near the Indian River has occurred only in the lower areas of the watershed. The upper watershed is completely surrounded by National Forest Service land that has not been harvested for timber. The City and Borough of Sitka owns land next to the Indian River that is zoned as residential and where housing units have been and continue to be developed. Further development is likely, because an additional 72 ha (180 acre) of land adjacent to the Indian River watershed are marked for this purpose (Neal et al. 2004). It is unclear what the downstream consequences of these developments will be, but they will likely include stormwater and urban runoff pollution (e.g. pesticides, fecal coliform, hydrocarbons).

Other development projects that are in the process of being planned include a landfill, a public safety academy driver training course, Sitka Counseling and Prevention Services (SCPS) housing and parking improvements, Sitka and Indian River trail improvements, and a CBS Electrical Department extension (CBS 2004). The landclearing landfill, a disposal site for organic topsoils and inorganic unsuitable soils, will cover 7.4 ha (18.5 acre) and require a significant road upgrade, which itself could adversely impact the watershed. The police academy is looking into building a new driver training course of approximately 3.52 ha (8.8 acre) to develop driver training skills. Again, the location of this new driving course will mean road development within the watershed as well as increased traffic. Sitka Counseling and Prevention Services plans to increase their number of parking spaces as well as construct new housing in a 1.1 ha (2.75 acre) area. Improvements to the Sitka Cross Trail and Indian River Trail include the construction of a bridge across the Indian River to connect the Cross Trail to Thimbleberry Lake, and the construction of an underpass under Sawmill Creek Road Bridge over the Indian River. The CBS Electrical Department plans to extend their 69KV distribution along the same route as the extension of the Sitka Cross Trail over the Indian River. The line would be buried 1.5 m (5 ft) below the trail surface. The City and Borough of Sitka is planning a small, 0.8 ha (2 acre) subdivision between Indian River Road and the Indian River. Each of these development plans has the potential to adversely impact the health of the Indian River watershed.

The Master Plan (CBS 2004) also states that much of the remaining undeveloped property within the Indian River watershed is owned by Sheldon Jackson College and may be sold for new low-income housing developments. The City and Borough of Sitka also has more land in the watershed on the east side of the Indian River that could be potentially developed at some time in the future. If construction in these areas occurs in the future, it could mean the alteration of a large amount of land in the watershed, although these two developments are not currently being planned.

Other future development plans being discussed by SJC and the city include a new deepwater cruise ship dock. One proposed location for this dock is on Sheldon Jackson property adjacent to the northwest park boundary. Having cruise ships dock so close to SITK will most likely bring numerous impacts, including increased air pollution coming from the ship; an increase in the concentration of water pollutants coming off the dock, ships, and docking facilities; increased turbidity of ocean water by stirring up bottom sediments; and increasing the sedimentation of the intertidal zone (see *C4. Marine Vessel Impacts* for other possible impacts). A deepwater dock could also lead to the interference of longshore currents and the disruption of freshwater and ocean mixing in estuarine areas.

C3. Nuisance Species

The National Invasive Species Council, which was created by Presidential Executive Order 13112, defines invasive species as species that are "nonnative (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health." The introduction of invasive species into Alaskan waters may be either accidental or due to negligence, and pathways of introduction include fish farms, aquaculture, transport on or in ballast water from ships or fishing vessels, live seafood trade, or sport fishing gear (ADFG 2002a). In order to minimize the impact of invasive species in Alaska, the Alaska Department of Fish and Game (ADFG) developed an Aquatic Nuisance Species Management Plan (ADFG 2002a) with the purpose of focusing on preventing the invasion of those invasive species that are considered the highest threat. This plan can be found on the ADFG Invasive Species Website at http://www.adfg.state.ak.us/special/invasive/invasive.php.

Nonindigenous aquatic invasive species that have been introduced or are moving into Alaskan waters include multiple species of fish, plants, and invertebrates (Appendix 5). Water bodies of Alaska are likely to be invaded by nonindigenous species because the temperature ranges of oceans, rivers and lakes vary much less than terrestrial temperature ranges (ADFG 2002a). Northern pike and yellow perch are invasive fish species that have been introduced to some areas of Alaska but are not present on Baranof Island and unlikely to survive in the Indian River (Geoffrey Smith, NPS-SITK, personal communication 2005). Farmed Atlantic salmon in Washington State and British Columbia are acidentally released into the North Pacific Ocean each year and may affect native populations through disease, colonization, interbreeding, predation, habitat destruction, and competition (ADFG 2002b). These farmed fish are thriving in the wild with recoveries in both British Columbia and Alaska, with the first catches of Atlantic salmon in Southeast Alaska in 1991 (ADFG 2002b). ADFG has documented over 700 recoveries of Atlantic salmon throughout Alaskan waters which represent an estimated 3,000 immigrants per year. Atlantic salmon have been caught in many locations throughout Southeast Alaska including Lynn Canal, Icy Strait, Ketchikan, Petersburg, and Yakutat (ADFG 2002b). Atlantic salmon pose a real threat to SITK, and although they have not yet been documented in the park, their appearance may be likely.

The most likely invasive marine invertebrate species of concern is the green crab (*Carcinus maenas*) which is originally from northern Europe, became established in California in the 1990's, and has since become established in estuaries as far north as British Columbia. Bacteria, viruses, and parasites are also a threat to Alaskan waters because these can be easily introduced through nonindigenous species. Whirling disease (*Myxobolus cerebralus*), a parasitic infection in trout and salmon is present in all western states except Alaska and Arizona, and the likelihood of establishment in Alaska is poorly understood (ADFG 2002a). Various aquatic nuisance plants that are potential or actual threats in Alaska include hydrilla a/k/a water thyme (*Hydrilla verticillata*), dotted duckweed (*Landoltia* (*Spirodela*) *punctata*), purple loosestrife (*Lythrum salicaria*), Eurasian water-milfoil (*Myriophyllum spicatum*), reed canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatum*), salt marsh cordgrass (*Spartina alterniflora*), dense-flowered cordgrass (*Spartina densiflora*), foxtail barley (*Hordeum jubatum*), and swollen bladderwort (*Utricularia inflata*) (Appendix 5, ADFG 2002a).

SITK has quite a few exotic plants within park boundaries as determined by two different studies within the Park (Table 8, Lipkin and Carlson 2004, McKee 2004). Developed trails, lawns, and historical sites are corridors for nonnative species, and although most appear to be restricted to disturbed areas, several may be spreading into less disturbed forested habitats. Most of these invasive plants are terrestrial and include pineapple weed (*Maricaria discoidea)*, annual bluegrass (*Poa pratensis)*, creeping buttercup (*Ranunculus repens)*, common dandelion (*Taraxacum officinalis)* and European mountain-ash (*Sorbus aucuparia*). Japanese knotweed (*Polygonum cuspidatum*) affects watersheds and its establishment in the SITK is of great concern, because it can be very aggressive. Japanese knotweed is known to spread rapidly, choking out native plants, and can spread along streambanks, shorelines, and estuaries. The resulting loss of springtime cover and woody streamside vegetation causes destabilized stream banks and less woody debris in the stream. So far, a few small plants have been found in small patches southeast of the visitor center next to the Indian River footbridge (Lipkin and Carlson 2004). The NPS is taking steps to eradicate it. The extensiveness of creeping buttercup in the park has recently been noted in a 2005 exotic plant survey (W. Rapp, NPS, in progress). This aggressive plant is especially troubling because of its ability to reproduce rapidly by creeping over and covering native ground plants. It has taken over large areas. Its wide tolerance to light levels has allowed it to not only thrive in disturbed areas adjacent to the trail system but also to move into heavily shaded forest areas.

Terrestrial exotic animal species in SITK include rock dove (*Columba liva*), European starling (*Sturnus vulgaris*), domestic dogs and cats, and possibly the Norway rat (*Rattus norvegicus*). Little is known about the impacts these species are having on park ecosystems. Populations of starlings in particular appear to be rapidly increasing in the Sitka area. Observations of starlings foraging in the park's intertidal zone and tidal meadow have become much more numerous and the flock sizes have dramatically increased. Starlings may be breeding in the park (Geoffrey Smith, NPS-SITK, personal communication 2005).

C4. Marine Vessel Impacts on Water Quality

Marine vessels have the potential to degrade water quality in SITK by the accidental release of petroleum (discussed above in *B3a3. Petroleum spills*), the release of wastewater or other discharges, or by resuspension of sediments (NPS 2003). Over half SITK's boundary is intertidal shoreline, and as mentioned previously, SITK leases and manages 50 acres of tidelands from the city of Sitka and the State of Alaska, therefore there is the possibility that this intertidal area could be impacted by contaminants from a marine vessel at some time in the future.

Wastewater generated by marine vessels that may serve as a source of marine pollution in or near SITK waters includes graywater (laundry, shower, and galley sink wastes), blackwater (treated sewage), hazardous waste, solid waste and marine debris (NPS 2003). Alaska Department of Environmental Conservation (ADEC,2002) reports that dilution levels for small marine vessels that treat and continuously discharge their wastewater is extremely high, and the only contaminant likely to be measured above ambient water levels would be fecal coliform bacteria. It is illegal to dump raw sewage within 5 km (3 mi) of shore, and therefore no discharge should occur near SITK. Private vessels may not be able to treat their wastewater before it is discharged, however NPS (2003) reports that because of the small volumes and large dilution factor, that the effects of this wastewater would not be significant. Another potential pollution source is solid waste, including food waste, plastic and glass

Table 8. Exotic plant species found within Sitka National Historical Park, Alaska during summer 2004, from McKee (2004) and Lipkin and Carlson (2004).

Species	**Common Name**	**Location Description**
Capsella bursa-pastoris	Shepherds purse	None given
Cerastium fontanum	Chickweed	None given
Chenopodium album	Lambsquarters	None given
Digitalis purpurea	Foxglove	Upper parking lot and small clearing behind park visitor center
Leucanthemum vulgare (Chrysanthemum leucanthemum)	Oxe-Eye Daisy	In small clearing behind Dark visitor center
Matricaria discoidea (Matricaria matricarioides)	Pineapple Weed	In lawn in front of park visitor center
Phleum pratense	Timothy	None given
Plantago major	Common Plantain	Extensive in lawn in front of park visitor center and at rest area facing ocean near old battle site
Poa annua	Annual bluegrass	None given
Poa pratensis	Kentucky bluegrass	None given
Polygonum convolvulus	Black bindweed	None given
Polygonum cuspidatum	Japanese Knotweed	In small patches next to Indian River footbridge
Ranunculus repens	Creeping Buttercup	Extensive at old fort site and sporadic along some park trails
Sorbus aucuparia	European Mountain Ash	Possible hybrid varieties growing on coastal trailside section
Taraxacum officinale	Common Dandelion	Abundant in lawn in front of park visitor center and rest areas along ark trails
Trifolium pratense	Red Clover	None given
Trifolium repens	White Clover	Common in lawn in front of visitor center, rest areas along park trails and at old fort site

containers, and paper products, however plastics and any garbage except dishwater, graywater, and fresh fish parts are not legally dumped within 5 km (3 mi) of the coast.

Another way in which vessels can affect water quality is by resuspending sediments in marine waters through vessel movement, which can cause increased turbidity that can interfere with filter feeding organisms and decreased water quality by reducing light penetration (NPS 2003). The amount of sediment resuspension depends on the speed and size of the vessel, the sediment size, and the stability of the water column (NPS 2003). The effects to water quality in SITK are most likely temporary and limited to the immediate area of vessel traffic.

C5. Harmful Algal Blooms

Harmful algal blooms (HABs) are caused by a few dozen marine phytoplankton that produce toxins. Although commonly called red tides, this term is misleading as with many HABs, there is no discoloration to the water, and many seaweeds produce colored blooms. HABs cause significant ecosystem, human health, and economic impacts (Anderson et al. 2000). HABs have become a national and international research focus in the past decade. Most areas of the world have some form(s) of harmful algal bloom, although the frequency, severity and diversity vary greatly. One thing that is certain is that HABs have been occurring more frequently and in more areas during the past few decades (Anderson 1995, Burke et al. 2000). HABs have caused mass mortalities of marine bird, mammal, and fish populations, and they cause a variety of human illnesses that vary by type of toxic phytoplankton or diatom. Some cause respiratory problems in humans in certain geographic regions. Southwest Florida, for example, now issues health alerts and suggests that people with certain health problems stay inside and away from beaches during certain blooms. HABs are known to cause a variety of shellfish poisoning (SP), including paralytic (PSP), diarrhetic (DSP), neurotoxic (NSP), and A fifth human illness, caused by finfish and not shellfish, is Ciguatera the dinoflagellate Poisoning (CFP).

Harmful algal blooms have been documented for centuries. Early records from explorers and hunters describe outbreaks of illness after men ate local shellfish that are most likely the result of ingesting intoxicated shellfish. First recorded deaths due to PSP occurred during exploration of Puget Sound and Strait of Georgia in 1791-1792 when several members of Capt. George Vancouver's crew died after eating shellfish from a cove near modern day Vancouver, BC. The earliest recorded event in Alaska was in 1799 when a party of Aleut hunters under the command of a Russian fur trading company ingested mussels. Within minutes, half the party experienced nausea and dry mouth, and two hours later, 100 hunters had died. Alaska has figured prominently in the discovery of HABs and associated toxins, as the family of toxins responsible for PSP were named saxitoxins because they were extracted from the butter clam *Saxidomus giganteus* from Peril Strait, just northeast of Sitka.

The largest problem caused by HABs in Alaska is paralytic shellfish poisoning (PSP) from shellfish that have bioaccumulated the dinoflagellate *Alexandrium* sp. (Figure 13). Alaska has one of the highest incidences of reported PSP in the world (Gessner and Schloss 1996).

Paralytic shellfish poisoning can cause paralysis, gastrointestinal problems, and respiratory arrest and can be fatal if prompt medical care and respiratory support is not available. There is no antidote. People have died in Alaska from PSP as recently as a decade ago, and there is at least one human health incident per year. Since 1973, there have been 176 incidences of PSP in Alaska from 66 outbreaks, with the majority in Southeast Alaska (Figure 14, Gessner 1996).

Figure 13. *Alexandrium* sp., responsible for PSP

Figure 14. Location of PSP outbreaks in Alaska Each star represents one or more outbreaks. Source: Gessner 1996.

Little is known about the distribution or abundance of PSPs in coastal areas of SITK. The Alaska Department of Environmental Conservation (ADEC) is responsible for testing shellfish for PSP. Due to the geographic extent of Alaska (over 81,000 km (50,000 mi) of coastline) and the remote nature of many regions of the state, shellfish are only tested for PSP in association with a commercial harvest or mariculture facility. Non-commercial harvests are not tested, and people are advised not to eat shellfish that they collect. More information is needed in order to evaluate if HABs are an issue of concern in SITK. Any unusual incidences of mass mortalities of marine bird, mammal, and fish populations should be suspected as possible HAB-related events. NPS should advise against non-commercial harvests of shellfish because of the risks associated with PSP.

C6. Physical Impacts

Human use of SITK is of historical importance and dates back to the 1700s; however, human use has modified the natural state of the park and its associated watershed. Physical impacts, assessed by summarizing past records and by comparing aerial photography, include beach dredging, lower delta dredging, trailer court fill, the buried asphalt plant, and channel dredging (Chaney et al. 1995). Paustian and Hardy (1995) report that since the 1940s, channel and streambank modifications include three major changes to the lower Indian River: 1) straightening of a meander in the channel in 1945, diverting most of the river flow along the west bank of the estuary, 2) placement of a riprap wall above a gravel island at the head of the estuary in 1961, significantly constricting the natural channel, and 3) lining of the entire west bank of the estuary with toed-in shot-rock riprap in 1985. We discuss below the two types of physical impacts that are major issues facing the Indian River watershed, erosion and sedimentation.

C6a. Erosion

Shoreline erosion has been a concern in SITK since 1940 (Molnia 1980). Gravel extraction took place during WW II and intermittently up to 1978, and this activity created a 60 foot deep hole at the mouth of the Indian River and removed a total of 1.1 million cubic m (1.5 million cubic yds) of material. This drastic altering of the mouth of the river is suspected to be responsible for "increased channel bed scour and channel entrenchment in the estuary channel segment due to temporary lowering of the river's base level" (Paustian and Hardy 1995a). This dredging is believed to have changed the gradient of the river and caused increased erosion along the bank.

In 1979 the owner of a trailer court just north of SITK illegally put fill into Indian River in order to enlarge the size of his property. This action unfortunately accelerated erosion of the bank where the historic Kiksadi Tlingit fort was located. In 1981 the Corps of Engineers ordered the fill removed because the permitting process was not followed properly; however, the trailer court owner ignored the order. As a result, the Indian River established a meander that intensified erosion of the bank adjacent to the fort site, with the rate of erosion at two to eight feet annually (Antonson and Hanable 1987). In order to stabilize the riverbank adjacent to the fort site and halt erosion in this area, NPS installed 3,105 cubic m (4,600 cubic yds) of toed-in armor shot-rock rip-rap and backfill along the riverbank in 1985, and in the next year 877 cu m (1,300 cubic yds) of stones were scattered along the river bank for stabilization (Antonson and Hanable 1987). After the Antonson and Hanable (1987) report, erosion at the fort site was no longer addressed and is not currently a problem (Geoffrey Smith, NPS-SITK, personal communication 2005).

Movement of sand and gravel in estuary and intertidal areas is a natural process that will and should continue (Figure 8). Between 1950 and 1985, high rates of erosion were observed along the west side of the estuary (Antonson and Hanable 1987). Strong erosion is still occurring, although now on the east side of the estuary. The estuary channel has been establishing a new meander pattern that is nearly a mirror image of the river's pre-1940s channel configuration (Paustian and Hardy 1995). During winter storms in November and December, erosion up to 1.2 to 1.8 m (4 to 6 ft) per year occurs along the east side of the river (Shannon & Wilson 1995). Riverbank erosion will continue, with unclear consequences to the currents and habitat structure of the intertidal and near-shore zone (Chaney et al. 1995). Future coastal development that may include cruise ship docks or a runway extension at the Sitka airport could potentially influence current patterns and tidal exchange in coastal areas of SITK as well.

C6b. Sedimentation

Sediment transport alterations in the Indian River are a cause for concern due to streamflow diversions and trapping by the dam. Sheldon Jackson College owns and operates a dam on the lower Indian River at km 1.3 (mile 0.8) for the purposes of supplying water to the SJC fish hatchery. The dam provides no flood attenuation because it does not have a significant storage volume (CBS 2004). However, the dam traps a large amount of coarse sediment that would otherwise be carried downstream. By starving the downstream channel of sediment, the dam promotes the scour and erosion of riverbanks downstream (Chaney et al. 1995). In addition, the water diversion occurring at the dam site effectively decreases the river's flow and its capacity to move sediment downstream (Chaney et al. 1995). As a result, the reduced streamflow may result in the accumulation of more sediment downstream of the dam than would be expected without the dam. Diminished streamflow in the lower channel may have deleterious effects on macroinvertebrate habitat and fish spawning sites.

C6c. Uplift Rates

Active tectonics in Southeast Alaska as well as the increased thinning of glaciers are contributing to the extremely high rates of land surface uplift in the region. Icefields in coastal Southeast Alaska have experienced rapid retreat and thinning in the last 100-200 years, and the rate at which ice is being lost appears to be increasing (Arendt et al. 2002). The unloading of the earth's surface associated with this loss of ice has resulted in isostatic rebound of the earth's crust over a large area of Southeast Alaska (Hicks and Shofnos 1965, Clark 1977, Sauber et al. 2000, Larsen et al. 2004). Over the past 250 years, shorelines in the upper Lynn Canal north of SITK have been raised between 3 and 5.7 m (9.8 and 18.7 ft) primarily as a result of land surface uplift (Larsen et al. 2004). Recent measurements of uplift in Southeast Alaska are among the highest ever recorded with rates of up to 25 mm (1 in) per year in Glacier Bay and 34 mm (1.33 in) per year centered over the Yakutat Icefield (Larsen 2003). However, the SITK area is experiencing a comparatively minimal amount of uplift—approximately 1-2 mm (0.4 to 0.8 in) per year (Larsen 2003). As a result, many of the landscape, hydrological, and ecological alterations created by rapid uplift elsewhere in Southeast Alaska are not an issue in SITK.

C7. Climate Change

Climate change is an important natural resource issue for national parks in Alaska and recent research suggests that changes in climate may dramatically impact water resources in these parks. On a global scale, mean surface air temperature has risen by about 0.6 ºC in the last century and the best estimate of the International Panel on Climate Change is that temperatures will rise by another 1.7 to 4.0 ºC by 2100 (IPCC 2001). Recent climate change is dominated by human influences and there is now a relatively broad scientific consensus that the primary cause of climate change is human-induced changes in atmospheric composition (Karl and Trenberth 2003). In particular, the concentration of greenhouse gases such as carbon dioxide and methane which absorb and re-radiate outgoing terrestrial longwave radiation have rapidly increased. Models and recent observations both suggest that climate warming is amplified at higher latitudes (Hall 1988, Mitchell 1989, Serreze et al 2000), and changes in temperature will be proportionally higher in high latitude systems (Roots 1989). Over the past fifty years, Siberia, Alaska and northern Canada, and the Antarctic Peninsula have warmed more than any other regions on Earth. The reasons for observed temperature increases at high latitudes are not fully understood, but are thought to involve cyospheric feedbacks, coupled with changes in the atmospheric circulation, and possibly ocean currents.

This warming in high-latitude regions is already affecting the physical landscape in Alaska. The most obvious effects of climate change on hydrologic resources in Alaska are changes in the extent of permafrost, snow cover, glaciers, and sea and lake ice cover (Oswood et al. 1992). Glaciers in both maritime and continental regions of Alaska are thinning and retreating at rapid rates (Arendt et al 2002). Meteorological data from the nearby stations at Juneau, Sitka and Yakutat show a tendency toward an increase in average summer air temperature since about 1940 when the meteorological record began (e.g. Motyka et al. 2002).

While the effects of glacier retreat may not be directly relevant to SITK, the disappearance of permanent snowfields, such as those in the upper portions of the Indian Creek watershed, will likely create important hydrological changes. A major effect of increased melt from permanent snowfields is a short-term increase in runoff to streams. Increased runoff can lead to the creation of new streams, and can alter the sediment, streamflow, and temperature regimes in the surrounding streams (Oswood et al. 1992). Moreover, stream channel morphology and stability would be altered by changes in runoff and sediment loads, as well as the composition of the substrate and habitat complexity of the stream (Williams 1989). Reduced stream temperatures from increased snowmelt could also decrease primary production, impact or eliminate certain invertebrates, and lower salmonid rates of production (Lloyd 1987, Lloyd et al. 1987). As the snowfields melt and shrink, their contribution to streamflow will eventually be diminished and exhausted. The elimination of this water source may have significant effects on baseflow levels in streams. Streamflow may markedly diminish or even run dry during portions of the year when they would normally be sustained by snowmelt, and this hydrological alteration would have cascading effects on stream-dependent biota.

The effects of climate change on the chemistry of lakes and streams are unknown. However, research on linkages between terrestrial and aquatic system suggest that elevated temperatures and carbon dioxide levels will affect the distribution and productivity of plants which will in turn affect the amount and quality of leaf litter entering streams and rivers (Meyer and Pulliam 1992). Sweeney et al. (1992) suggest that there will also be an increase in woody debris entering streams. Because soil microbial activity is linked to soil temperature and moisture, climate shifts will affect microbial processing of organic material in terrestrial systems. Overall, changes in inputs from terrestrial systems to lakes and streams will lead to shifts in litter decomposition rates (Webster and Benfield 1986), as well as changes in the productivity of heterotrophic and invertebrate populations (Anderson and Sedell 1979, Oswood et al. 1992). Stream water quality could also be altered by changes in the frequency of disturbances such as forest fires, wind storms, coastal floods (Meyer and Pulliam 1992). Ultimately, changes to the quality and quantity of runoff from terrestrial ecosystems will affect near-shore marine systems in coastal SITK because the productivity of these systems is partially controlled by the input of nutrients from coastal watersheds.

D. Recommendations

D1. Condition overview

Table 9. Potential for impairment of SITK water resources.

Indicator	Freshwater / Indian River	Estuary	Marine/ Intertidal
Water Quality			
Eutrophication	OK	OK	OK
Contaminants	PP	PP	PP
Hypoxia	OK	OK	OK
Turbidity	OK	OK	OK
Pathogens	OK	OK	OK
Habitat Disruption			
Physical benthic impacts	OK	OK	OK
Coastal development	PP	PP	PP
Altered flow	EP	OK	OK
Erosion/Sedimentation	EP	EP	OK
Altered salinity	NA	OK	OK
Other Indicators			
Harmful algal blooms	NA	PP	PP
Aquatic invasive species	PP	PP	PP
Impacts from fish/shellfish harvesting	PP	OK	OK
Climate change	PP	PP	PP

Definitions: EP= existing problem, PP = potential problem, OK= no detectable problem, shaded =limited data, NA= not applicable.

SITK is relatively pristine with few problems of concern, however in many cases, little data is available (Table 9). Our rationale for assignments is described below.

Freshwater/Indian River – Water quality in the Indian River from all accounts appears to be high. Habitat disruption could occur from coastal development and the existing dam, which causes altered flow, erosion, and sedimentation. Atlantic salmon could become a nuisance species if they were to establish in the river, however they have not been observed to date. Given that the predominant species of salmon are pink and chum salmon, there is little reason to expect that fishing pressure would be high if fishing were to be allowed in the river. Climate change effects are unknown but could be significant at high latitudes.

Estuary – Water quality in estuarine areas is high. Coastal development could affect estuarine habitats. Effects of the dam will affect estuarine areas at the river mouth, with effects on erosion and sedimentation. No sampling has been done to evaluate the presence of harmful algal blooms or aquatic invasive species. Climate change effects are unknown but could be significant at high latitudes.

Marine/Intertidal – Water quality in marine and intertidal areas is high in the region, however no sampling has been conducted within the park. Coastal development could disrupt marine and intertidal habitats. No sampling has been done to evaluate the presence of harmful algal blooms or aquatic invasive species. Given the prevalence of harmful algal blooms, clam or mussel harvest should be discouraged. Impacts from fish or shellfish harvesting are unknown, largely because the amount of harvest from the park is not well known. Climate change effects are unknown but could be significant at high latitudes.

D2. Recommendations

During the course of writing this report, we identified data gaps and areas in which further investigation or monitoring is warranted. These recommendations are enumerated below (Table 10) and elaborated in the following section.

Table 10. List of recommendations.

Data access/management

3. Online archives of NPS publications and reports
4. Integration of information into centralized and web-accessible GIS

Water quality

3. Monitoring of water quality in the Indian River
4. Targeted monitoring of effects of nearby development

Biological resources and habitats

4. Intertidal monitoring program
5. Identification of sentinel species
6. Vessel survey

Hydrology/Oceanography

4. Identification of generalized circulation in Sitka Sound
5. Monitor streamflow, sedimentation, and erosion in the Indian River and estuary
6. Monitor physical parameters to detect how changes in climate may be affecting hydrologic resources

D2a. Data access/management

Online archives of NPS publications and reports

Obtaining information for this report was arduous and difficult, however information could be more readily obtained if NPS were to generate online archives of NPS publications and reports. Such an archive should be searchable. Historical documents should be entered to the extent possible.

Integration of information into centralized and web-accessible GIS
Data from surveys, monitoring activities, impairments, and inventories should be integrated into a centralized and web-accessible GIS.

D2b. Water quality

Monitoring of water quality in the Indian River
The Indian River is central to biotic resources in SITK, so it is important to implement a long-term water quality monitoring program. Water quality testing that has been conducted by NPS-SITK to date should be summarized in a report and formalized into a regular program in partnership with NPS WRD or I&M. This approach will allow SITK to monitor the discharge from SJC and any other developments occurring upstream in order to determine if upstream development is affecting water quality. It is also important to continue to monitor the north bank where erosion of the site of the old asphalt plant may allow contaminants to enter the river. The release of pollutants into the Indian River could be episodic and water quality should, ideally, be monitored continuously. It is especially important to monitor after storm events when upstream construction is taking place. We also recommend implementing formalized biological sampling of macroinvertebrates and flora to detect any changes in community structure that may result from chronic or pulsed impacts. The USGS study (Neal et al. 2004) can be used as a baseline for future monitoring activities.

Targeted monitoring of effects of nearby development
Increased urbanization in the Sitka area and, particularly in the Indian River watershed, will likely cause impacts on water quality. Water quality should be monitored before, during, and after planned development activities within the watershed.

D2c. Biological resources and habitats

Intertidal monitoring program
The intertidal monitoring program should be continued, however NPS should require reports for work conducted to date and analyses of existing efforts to determine interval at which monitoring should be conducted. Monitoring should include an assessment of critical fish habitats and nursery areas in near shore areas. NPS should obtain GIS layers from ShoreZone to integrate into centralized GIS (see above) and should participate in ground-truthing for ShoreZone.

Identification of sentinel species
Biological resources and habitats and water quality may be inferred if sentinel species are identified that indicate status of resources. For example, the presence of American dippers in the Indian River may be good indicators of high water quality; however such a relationship needs to be verified.

Vessel survey
The number and type of vessels located within ~3 km of the park could be inventoried during high use period to evaluate potential risk to coastal habitats from oil spills or other marine vessel discharges.

D2d. Hydrology/Oceanography

Identification of generalized circulation in Sitka Sound

Little is known about generalized circulation in Sitka Sound, however it is necessary to identify which areas are upstream and could affect conditions within the park. Future modifications within Sitka Sound could change circulation patterns, and therefore, determination should be made before and after any construction projects (i.e. cruise ship docks, airport runway extension, etc.)

Monitor streamflow, sedimentation, and erosion in the Indian River and estuary

Water flow in the Indian River has the potential to greatly impact biotic resources and habitats. Monitoring streamflow above and below the dam on a regular basis will allow for temporal analysis of effects of water diversions. If water levels become critical, then action should be taken to restore flow. Sedimentation and erosion within and at the mouth of the Indian River are poorly understood and should be further investigated.

Monitor physical parameters to detect how changes in climate may be affecting hydrologic resources

Climate change is one of the major threats to water resources in Alaskan parks. The hydrology of coastal parks such as SITK is particularly sensitive to climate change because the air temperature at sea level in southeastern Alaska is often close to the freezing point of water. As a result a relatively small increase in temperature can shift precipitation from snow to rain which, in turn, shifts the annual pattern of streamflow in these coastal systems. Basic physical parameters in coastal SITK should be monitored. Data collection should be automated and continuous, with transmittal of information to national databases (i.e. NOAA, USGS). Physical parameters that should be monitored include: sea level height, sea temperature, salinity, air temperature, precipitation, and other weather and oceanographic factors. SITK should install an automated climate station to provide baseline climate information and aid SITK resource managers in detecting future changes in climate.

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Appendices

Appendix 1. A list of present and expected species of marine fishes for SITK compiled from Litzow et al. (2002), Piazza (2001) and G. Smith (NPS-SITK, personal communication 2005). Status P = present and E = expected.

Common name	**Scientific name**	**Status**
Cutthroat trout	*Oncorhynchus clarki*	P
Pink salmon	*O. gorbuscha*	P
Chum salmon	*O. keta*	P
Coho/silver salmon	*O. kisutch*	P
Rainbow trout	*O. mykiss*	P
Chinook/king salmon	*P. tshawytscha*	P
Dolly Varden	*Salvelinus malma*	P
Surf smelt	*Hypomesus pretiosus pretiosus*	E
Capelin	*Mallotus villosus*	E
Rainbow smelt	*Osmerus mordax dentex*	E
Night smelt	*Spirinchus starksi*	E
Longfin smelt	*Spirinchus thaleichthys*	E
Eulachon	*Thaleichthys pacificus*	E
Pacific herring	*Clupea pallasi*	P
Northern clingfish	*Gobiesox maeandricus*	E
Whitespotted greenling	*Hexagrammos stelleri*	P
Kelp greenling	*H. decagrammus*	P
Masked greenling	*H. octogrammus*	P
Rock greenling	*H. lagocephalus*	P
Lingcod	*Ophiodon elongates*	E
Painted greenling	*Oxylebius pictus*	E
Atka mackerel	*Pleurogrammus monopterygius*	E
Threespine stickleback	*Gasterosteus aculeatus*	E
Padded sculpin	*Artedius fenestralis*	P
Scalyhead sculpin	*A. harrintoni*	E
Smoothhead sculpin	*A. lateralis*	E
Rosylip sculpin	*Ascelichthys rhodorus*	E
Crested sculpin	*Blepsias bilobus*	E

Silverspotted sculpin	*Blepsias cirrhosus*	P
Mosshead sculpin	*Clinoccus globiceps*	E
Sharpnose sculpin	*Clinocottus acuticeps*	E
Calico sculpin	*Clinocottus embryum*	E
Buffalo sculpin	*Enophrys bison*	P
Red Irish lord	*Hemilepidotus hemilepidotus*	P
Pacific staghorn sculpin	*Leptocottus armatus*	P
Great sculpin	*Myoxocephalus polyacanthocephalus*	P
Tidepool sculpin	*Oligocottus maculosus*	P
Saddleback sculpin	*O. rimensis*	E
Fluffy sculpin	*O. snyderi*	E
Grunt sculpin	*Rhamphocottus richardsonii*	E
Cabezon	*Scorpaenichthys marmoratus*	P
Rockhead	*Bothragonus swanii*	E
Tubenose poacher	*Pallasina barbata*	P
Spotted snailfish	*Liparis callyodon*	E
Tidepool snailfish	*L. florae*	P
Penpoint gunnel	*Apodichthys flavidus*	P
Tube-snout	*Aulorhynchus flavidus*	P
Shiner perch	*Cymatogaster aggregate*	P
Pacific cod	*Gadus macrocephalus*	P
Crescent gunnel	*Pholis laeta*	P
Starry flounder	*Platichthys stellatus*	P
Redstripe rockfish	*Sebastes sp.*	P
Manacled sculpin	*Synchirus gilli*	P
High cockscomb	*Anoplarchus purpurescens*	P

Appendix 2. Species list of birds present in Sitka National Historical Park (Piazza 2001 and G. Smith, NPS-SITK, personal communication 2005).

SCIENTIFIC NAME	COMMON NAME
Gavia stellata	Red-throated loon
Gavia immer	Common loon
Gavia adamsii	Yellow-billed loon
Gavia pacifica	Pacific loon
Podilymbus podiceps	Pied-billed grebe
Podiceps auritus	Horned grebe
Podiceps grisegena	Red-necked grebe
Aechmophorus occidentalis	Western grebe
Oceanodroma furcata	Fork-tailed storm-petrel
Oceanodroma leucorhoa	Leach's storm-petrel
Phalacrocorax auritus	Double-crested cormorant
Phalacrocorax pelagicus	Pelagic cormorant
Phalacrocorax urile	Red-faced cormorant
Ardea herodias	Great blue heron
Ardea alba	Great egret
Bubulcus ibis	Cattle egret
Cygnus columbianus	Tundra swan
Cygnus buccinator	Trumpeter swan
Anser albifrons	Greater white-fronted goose
Chen canagica	Emperor goose
Branta bernicla	Brant
Branta canadensis	Canada goose
Anas crecca	Green-winged teal
Anas platyrhynchos	Mallard
Anas acuta	Northern pintail
Anas discors	Blue-winged teal
Anas clypeata	Northern shoveler
Anas strepera	Gadwall
Anas penelope	Eurasian wigeon
Anas americana	American wigeon
Aythya valisineria	Canvasback
Aythya americana	Redhead
Aythya collaris	Ring-necked duck
Aythya marila	Greater scaup
Aythya affinis	Lesser scaup
Polysticta stelleri	Steller's eider
Histrionicus histrionicus	Harlequin duck
Clangula hyemalis	Long-tailed duck
Melanitta nigra	Black scoter
Melanitta perspicillata	Surf scoter
Melanitta fusca	White-winged scoter
Bucephala clangula	Common goldeneye

Bucephala islandica	Barrow's goldeneye
Bucephala albeola	Bufflehead
Lophodytes cucullatus	Hooded merganser
Mergus merganser	Common merganser
Mergus serrator	Red-breasted merganser
Pandion haliaetus	Osprey
Haliaeetus leucocephalus	Bald eagle
Accipiter striatus	Sharp-shinned hawk
Accipiter gentilis	Northern goshawk
Buteo jamaicensis	Red-tailed hawk
Falco sparverius	American kestrel
Falco columbarius	Merlin
Falco peregrinus	Peregrine falcon
Dendragapus obscurus	Blue grouse
Porzana carolina	Sora
Fulica americana	American coot
Grus canadensis	Sandhill crane
Pluvialis squatarola	Black-bellied plover
Pluvialis dominicus	American golden-plover
Pluvialis fulva	Pacific golden-plover
Charadrius semipalmatus	Semipalmated plover
Charadrius vociferus	Killdeer
Haematopus bachmani	Black oystercatcher
Tringa melanoleuca	Greater yellowlegs
Tringa flavipes	Lesser yellowlegs
Heteroscelus incanus	Wandering tattler
Actitis macularia	Spotted sandpiper
Numenius phaeopus	Whimbrel
Limosa haemastica	Hudsonian Godwit
Limosa lapponica	Bar-Tailed Godwit
Limosa fedoa	Marbled godwit
Arenaria interpres	Ruddy turnstone
Arenaria melanocephala	Black turnstone
Aphriza virgata	Surfbird
Calidris canutus	Red knot
Calidris alba	Sanderling
Calidris pusilla	Semipalmated sandpiper
Calidris mauri	Western sandpiper
Calidris minutilla	Least sandpiper
Calidris bairdii	Baird's sandpiper
Calidris melanotos	Pectoral sandpiper
Calidris ptilocnemis	Rock sandpiper
Calidris alpina	Dunlin
Philomachus pugnax	Ruff
Limnodromus griseus	Short-billed dowitcher
Limnodromus scolopaceus	Long-billed dowitcher

Gallinago delicata	Wilson’s snipe
Phalaropus lobatus	Red-necked phalarope
Stercorarius parasiticus	Parasitic jaeger
Stercorarius longicaudus	Long-tailed jaeger
Larus heermanni	Heermann’s gull
Larus philadelphia	Bonaparte's gull
Larus canus	Mew gull
Larus californicus	California gull
Larus argentatus	Herring gull
Larus thayeri	Thayer's gull
Larus glaucescens	Glaucous-winged gull
Larus hyperboreus	Glaucous gull
Rissa tridactyla	Black-legged kittiwake
Rissa brevirostris	Red-legged kittiwake
Sterna caspia	Caspian tern
Sterna paradisaea	Arctic tern
Uria aalge	Common murre
Cepphus columba	Pigeon guillemot
Brachyramphus marmoratus	Marbled murrelet
Fratercula cirrhata	Tufted puffin
Columba livia	Rock dove
Zenaida macroura	Mourning dove
Otus kennicottii	Western screech-owl
Bubo virginianus	Great horned owl
Nyctea scandiaca	Snowy owl
Glaucidium gnoma	Northern pygmy-owl
Aegolius acadicus	Northern saw-whet owl
Chordeiles minor	Common nighthawk
Calypte anna	Anna's hummingbird
Selasphorus rufus	Rufous hummingbird
Ceryle alcyon	Belted kingfisher
Sphyrapicus ruber	Red-breasted sapsucker
Picoides pubescens	Downy woodpecker
Picoides villosus	Hairy woodpecker
Picoides tridactylus	Three-toed woodpecker
Colaptes auratus	Northern flicker
Empidonax alnorum	Alder flycatcher
Empidonax difficilis	Pacific-slope flycatcher
Tyrannus verticalis	Western kingbird
Tachycineta bicolor	Tree swallow
Tachycineta thalassina	Violet-green swallow
Hirundo rustica	Barn swallow
Cyanocitta stelleri	Steller's jay
Pica pica	Black-billed magpie
Corvus caurinus	Northwestern crow
Corvus corax	Common raven

Parus gambeli	Mountain chickadee
Parus rufescens	Chestnut-backed chickadee
Sitta canadensis	Red-breasted nuthatch
Certhia americana	Brown creeper
Troglodytes troglodytes	Winter wren
Cinclus mexicanus	American dipper
Regulus satrapa	Golden-crowned kinglet
Regulus calendula	Ruby-crowned kinglet
Sialia currucoides	Mountain bluebird
Catharus ustulatus	Swainson's thrush
Catharus guttatus	Hermit thrush
Turdus migratorius	American robin
Ixoreus naevius	Varied thrush
Mimus polyglottos	Northern mockingbird
Anthus rubescens	American pipit
Bombycilla garrulus	Bohemian waxwing
Bombycilla cedrorum	Cedar waxwing
Sturnus vulgaris	European starling
Vermivora celata	Orange-crowned warbler
Dendroica petechia	Yellow warbler
Dendroica coronata	Yellow-rumped warbler
Dendroica townsendi	Townsend's warbler
Wilsonia pusilla	Wilson's warbler
Piranga ludoviciana	Western tanager
Spizella arborea	American tree sparrow
Passerculus sandwichensis	Savannah sparrow
Passerella iliaca	Fox sparrow
Melospiza melodia	Song sparrow
Melospiza lincolnii	Lincoln's sparrow
Zonotrichia atricapilla	Golden-crowned sparrow
Zonotrichia leucophrys	White-crowned sparrow
Zonotrichia querula	Harris' sparrow
Junco hyemalis	Dark-eyed junco
Plectrophenax nivalis	Snow bunting
Agelaius phoeniceus	Red-winged blackbird
Euphagus carolinus	Rusty blackbird
Euphagus cyanocephalus	Brewer's blackbird
Pinicola enucleator	Pine grosbeak
Loxia curvirostra	Red crossbill
Loxia leucoptera	White-winged crossbill
Carduelis flammea	Common redpoll
Carduelis pinus	Pine siskin
Carduelis tristis	American goldfinch

Appendix 3. Species list of aquatic macroinvertebrates found in the Indian River basin, Baranof Island, Sitka, Alaska
List compiled by Geoffrey Smith, Biologist, Sitka National Historical Park
Collection Period April 4, 2002 through July 22, 2005

Mayflies (Ephemeroptera)
Flat-bodied Clingers
Heptageniidae (*Epeorus* (3), *Rhithrogena, Cinygmula, Cinygma*):
Epeorus longimanus
Epeorus grandis
Epeorus sp. (Probably *E. deceptivus*, first set of gills are extended under the abdomen but do not meet to form a sucker-like structure.)
Rhithrogena futilis
Cinygmula sp.
Cinygma lyriforme
Swimmers
Baetidae (*Baetis):*
Baetis bicaudatus
Baetis tricaudatus
Baetis sp. (or *Diphetor hageni*?)
Leptophlebiidae (*Paraleptophlebia*):
Paraleptophlebia debilis
Ameletidae (*Ameletis*):
Ameletis validus
Sprawlers, Clingers--Stout bodied
Ephemerellidae (*Drunella* (3), *Serratella*):
Drunella grandis flavitincta
Drunella doddsi
Drunella coloradensis
Serratella tibialis

Stoneflies (Plecoptera)
Capniidae (*Capnia**): (Probably *C. nana*, *C excavate*, others?)
Leuctridae (*Paraleuctra, Despaxia*):
*Paraleuctra occidentalis**
*Despaxia augusta**
Nemouridae (*Zapada, Podmosta*):
*Zapada cinctipes**
*Zapada hays/oregonensis**
*Podmosta decepta**
Taeniopterygidae (*Doddsia*):
*Doddsia occidentalis**
Chloroperlidae (*Sweltsa, Suwallia, Kathroperla*):
*Sweltsa** (probably *S. borealis*, *S. oregonensis,* others?)
*Suwallia starki**
*Kathroperla perdita**

Perlodidae (*Megarcys, Kogotus*):
*Megarcys signata**
*Kogotus nonus**

* Identification verified by Dr. Kenneth Stewart. *Megarcys signata* verified by Robert Hood (USGS).

Caddisflies (Trichoptera)
Rhyacophilidae (*Rhyacophila*):
Rhyacophila verrula
Rhyacophila grandis
Brunnea Group (*R. vao*?)
Sibirica Group (*R. narvae*?)
Rhyacophila spp.
Glossosomatidae (*Glossosoma*):
Glossosoma penitum
Philopotamidae (*Dolophilodes*): (Small high-gradient creek, gravel and cobble bottom.)
Dolophilodes (Probably *D. pallidipes*)
Hydropsychidae [incl. Arctopsychidae] (*Parapsyche)*:
Parapsyche elsis
Phryganeidae (*Ptilostomis)*:
Ptilostomis ocellifera (Muskeg ponds in the Indian River Basin.)
Limnephilidae (*Chyranda, Dicosmoecus, Onocosmoecus, Ecclisomyia, Ecclisocosmoecus, Psychoglypha, Lenarchus, Limnephilus, Glyphopsyche*):
Chyranda centralis
Ecclisomyia conspersa
Ecclisocosmoecus scylla
Dicosmoecus atripes
Onocosmoecus unicolor
Psychoglypha subborealis
Psychoglypha sp. (Probably *P. alascansis*. *P. bella* may also be present.)
Lenarchus vastus (Temporary pools--Indian River flood plain and in muskeg ponds.)
Limnephilus spp. (Temporary pools in the Indian River flood plain.)
Glyphopsyche irrorata (Swan Lake)
Brachycentridae (*Micrasema*):
Micrasema gelidum/bactro
Lepidostomatidae (*Lepidostoma*):
Lepidostoma roafi
Lepidostoma sp.
Uenoidae (*Neophylax*):
Neophylax rickeri (Small high-gradient creek, gravel and cobble bottom.)

Collected specimens of the indicated species are catalogued and kept at Sitka National Historical Park.

Other Insects

True flies (Diptera)

Nonbiting Midges (Chironomidae):
Chironomidae geneses collected by Neal et al. (2004): *Brillia, Corynoneura, Eukiefferiella, Micropsectra, Parametriocnemus, Rheocricotopus*, *Stilocladius*, *Thienemanniella*. (Also Orthcladiinae, *Micropsectra/Tanytarus* sp. and *Cricotopus/Orthocladius* sp.)
Blackflies (Simuliidae): *Prosimulium* sp.
Crane Flies (Tipulidae): *Hesperoconopa* sp., *Dicranota* sp.
Dance Flies (Empididae): *Clinocera, Chelifera, Oreogeton*
No-see-ums (Ceratopogonidae)

Aquatic Beetles (Coleoperta)
(Amphizoidae): *Amphizoa* sp.
(Carabidae)

Springtails (Collembola)

Other Macroinvertebrates
Clams, Bivalvia (Sphaeriidae): *Pisidium* sp.
Roundworms (Nematoda)
Aquatic earthworms (Oligochaeta: Lumbriculidae, Naididae, Enchytraeidae)
Flat worms (Class Turbellaria)
Aquatic mites (Subclass Acari)

Appendix 4. Selected water quality standards for the State of Alaska (ADEC 2003). Standards for all parameters except fecal coliform bacteria refer to the criteria for the "Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife". Fecal Coliform bacteria refers to the "Water Recreation – contact recreation" criterion.

Parameter	Criteria
Fresh Water Standards	
Fecal Coliform Bacteria (FC)	In a 30-day period, the geometric mean of samples may not exceed 100FC/100 ml, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200FC/100 ml.
Dissolved Gas	Dissolved Oxygen (D.O.) must be greater than 7 mg/L in waters used by anadromous or resident fish. In no case may D.O. be less than 5 mg/L to a depth of 20 in the interstitial waters of gravel used by anadromous or resident fish for spawning. For waters not used by anadromous or resident fish, D.O. must be greater than or equal to 5 mg/L. In no case may D.O. be greater than 17 mg/L or exceed 110% of saturation.
Dissolved Inorganic	Total dissolved solids (TDS) may not exceed 1,000 mg/L. A concentration

Substances	of TDS may not be present in water if that concentration causes or could reasonably be expected to cause an adverse effect to aquatic life.
Petroleum, Hydrocarbons, Oils and Grease	Total aqueous hydrocarbons (TAqH) in the water column may not exceed 15μg/L. total aromatic hydrocarbons (TAH) in water may not exceed 10 μg/L. There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
pH	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH units outside of the naturally occurring range.
Sediment	The percent accumulation of fine sediment (0.1-4.0 mm) in the spawning grounds of anadromous or resident fish may not be increased more than 5% by weight above natural conditions. In no case may the fine sediment range in those gravel beds exceed a maximum of 30% by weight (as shown from grain size accumulation graph). In all other surface waters, no sediment loads (suspended or deposited) that can cause adverse effects on aquatic animal or plant life, their reproduction or habitat may be present.
Temperature	May not exceed 20˚C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15˚C Spawning areas 13˚C Rearing areas 15˚C Egg and fry incubation 13˚C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent the appearance of nuisance organisms.
Turbidity	May not exceed 25 nephelometric turbidity units (NTU) above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
Marine Water Standards	
Fecal Coliform Bacteria (FC)	Same as fresh water standard.
Dissolved Gas	Surface dissolved oxygen concentration in coastal water may not be less than 6.0 mg/L for a depth of one meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4 mg/L at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/L. the concentration of total dissolved gas may not exceed 100% of saturation.
Dissolved Inorganic Substances	Maximum allowable variation above natural salinity (parts per thousand): Natural Salinity — Human-Induced Salinity 0.0 to 3.5 — 1

	Greater than 3.5 to 13.5 2 Greater than 13.5 to 35.0 4
Petroleum, Hydrocarbons, Oils and Grease	Same as fresh water standard.
pH	May not be less than 6.5 or greater than 8.5. May not vary more than 0.2 pH units outside of the naturally occurring range.
Sediment	No measurable increase in concentration of settable solids above natural conditions, as measured by the volumetric Imhoff cone method.
Temperature	May not cause the weekly average temperature to increase more than 1C. the maximum rate of change may not exceed 0.5C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.
Turbidity	May not reduce the depth of the compensation point for photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.

The Alaska Water Quality Standards specify the degree of degradation that may not be exceeded in a waterbody as a result of human actions (ADEC 2003). The Alaska Water Quality Standards designate specific uses for which water quality must be protected, and specifies the pollutant limits, or criteria, necessary to protect these uses.

There are seven designated uses for fresh waters, and seven designated uses for marine waters specified in the Alaska Water Quality Standards (ADEC 2003). The seven freshwater uses are: drinking water; agriculture; aquaculture; industrial; contact recreation; noncontact recreation; and growth and propagation of fish, shellfish, other aquatic life, and wildlife. The seven marine water uses are: aquaculture; seafood processing; industrial; contact recreation; noncontact recreation; growth and propagation of fish, shellfish, other aquatic life, and wildlife; and harvesting for consumption of raw mollusks or other raw aquatic life. For each of these uses, the Alaska Water Quality Standards specify criteria for a variety of parameters or pollutants, which are both numeric and descriptive (ADEC 2003). According to the federal Clean Water Act Section 305(b) and Section 303(d), waterbodies are compared to the criteria for these parameters to determine if persistent water quality violations occur, and if so into which status category waterbodies are listed.

Appendix 5. Nonindigenous aquatic nuisance species that have invaded or could soon invade Southeast Alaska.
The species listed are all highly invasive, have caused severe impact in areas they have spread to, and are capable of living in Alaska's climate. Many of these species have already spread to the Pacific Northwest and are a risk to Alaska. From ADFG (2002a).

Species	**Originally from…**	**Now located in…**	**Why it is a concern**
Fish:			
Northern Pike	Alaska	Spreading to other areas of Alaska	Highest priority threat to Southcentral Alaska. They eliminate or greatly reduce the native species. Cause damage to resident species (rainbow trout and grayling). Potential impact to coho salmon stocks.
Atlantic Salmon	Escape from Fish farms in BC and Washington	Cordova Ketchikan Yakutat Bering Sea	Serious threat to native species due to competition in stream habitat. Displace native fish by out-competing for food and spawning habitat.
Yellow perch		Kenai Peninsula	Compete with all resident fish species and salmon fry. This population has been eradicated.
Ornamental aquarium fish			Compete with and may feed on native species.
Invertebrates:			
Green crab	N. Europe	California to Vancouver Island	Out-competes resident species for shoreline habitat. Very aggressive.
New Zealand mud snail	New Zealand	Europe Asia Idaho Montana Wyoming California Arizona	May impact the food chain for native trout and the physical characteristics of streams themselves. A serious threat to Alaska's sport fisheries.
Chinese mitten crab	China	San Francisco Bay/delta Possible it is in Oregon's Columbia River	Similar life history to American eel and can move upriver hundreds of miles displacing native species. Feeds on salmonid eggs.
Zebra mussel	Europe	Great Lakes	Out-compete resident mussels, clog water intake lines, sequester nutrients for primary production.
Signal crayfish	W. Canada	Kodiak Island	Out-compete stream fauna, eat everything, can survive extended periods of drought and famine.
Spiny water flea	Europe	Great Lakes California	Displaces existing zooplankton communities but is unpalatable to fish resulting in lower fish numbers.
Parasites:			
Whirling disease	Eurasian continent	Present in 22 states. Found in all western states except Arizona and Alaska.	Parasitic infection that attacks juvenile trout and salmon. Causes fish to swim erratically and in severe cases, to die.

Species	Originally from…	Now located in…	Why it is a concern
Plants:			
Hydrilla or water thyme	Originally from S. India and Korea.	Present in 15 states including California and Washington	Hydrilla is a noxious water weed that can quickly spread to become an impenetrable mat. Fills lakes and rivers completely until i "tops out" at the surface. Native plants are out-competed. Greatly slows water flow and clogs the area. Can alter water chemistry an oxygen levels. Hinders fish development.
Dotted duckweed	Australia and Southeast Asia	Present in 22 states including Oregon	This small floating plant grows rapidly into dense masses in still water covering the entire surface in a green "bloom".
Purple loosestrife	Eurasia	Present in all states except Hawaii and Alaska Also found in Canada.	Loosestrife is able to rapidly establish and replace native vegetation with a dense, homogeneous stand that reduces local biodiversity, endangers rare species and provides little value to wildlife.
Eurasian water-milfoil	Europe and North Africa	Present in 46 states including Alaska	Found in a variety of habits, becoming established in both impoundments and natural waters, sometimes brackish water or in clear, cool, spring-fed rivers. Problems include displacement of native vegetation, disruption of navigation and recreation by the formation of impenetrable mats, and decreased water flow.
Reed Canary grass	Eurasia	All but the southeastern portion of the US including Alaska.	Is invading freshwater wetlands and in some places choking channels of small streams. It creeping rhizomes out-compete native grasses leading to less biodiversity.
Japanese knotweed	Great Britain	Sitka Juneau Other Southeast Alaska areas	Spreads rapidly, choking out native plants. Can spread along streambanks, shorelines, and estuaries. Loss of springtime cover and woody streamside vegetation causes destabilized stream banks and less woody debris in streams.
Foxtail barley	Western North America	Juneau Interior Alaska	Invades salt marsh habitats
Salt marsh cordgrass	Eastern seaboard of the US from Maine to Texas	Has spread to Canada and western US including Washington, Oregon, and California.	Able to trap sediment leading to higher deposition rates. Changes water circulation patterns. Competitive replacement of native plants and impacts native flora and fauna in intertidal zone. Also, decreases production o bottom-dwelling algae, changes bottom-dwelling invertebrate populations, and loss o shorebird foraging areas.
Dense-flowered cordgrass	Chile South America	California	Outcompetes native flora and impacts native fauna. Eliminates foraging habitat for shorebirds and waterfowl. Dense clusters slo the flow of water and increase sedimentation (raising the wetland).
Swollen bladderwort	Southeastern U.S.	Western Washington	Grows in still or slow-moving water and forms dense beds of floating plants. Impacts native plants and animals and water quality.

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-73, January 2006